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BOLSA BAY, CALIFORNIA, PROPOSED OCEAN ENTRANCE SYSTEM STUDY

Report 3

TIDAL CIRCULATION AND TRANSPORT COMPUTER SIMULATION AND WATER QUALITY ASSESSMENT

SECTION 1: CALIFORNIA COASTAL COMMISSION'S 1986 CERTIFIED LAND USE PLAN AND SECONDARY ALTERNATIVE

by

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Numerical simulation	Tidal velocities	Wetlands

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

The State of California, State Lands Commission (SLC), is reviewing a plan for a new ocean entrance system as part of a multi-use project. This project involves both State and private property in the proposed development by SLC, Signal Landmark, and others. The project, located in the Bolsa Chica area of the County of Orange, California, includes navigational, commercial, recreational, and residential uses, along with major wetlands restoration. The County of Orange approved a Land Use Plan (LUP) in 1985 as part of the Local Coastal Program for Bolsa Chica in accordance with the California Coastal Act of 1976. This same LUP was certified by the California Coastal Commission (CCC) with conditions in 1986. Part of the LUP certification requirement to satisfy those conditions includes confirmation review of modeling studies of a navigable and a non-navigable ocean entrance at Bolsa Chica.

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Bolsa Bay, California, Proposed Ocean Entrance System Study: Report 3, Tidal Circulation and Transport Computer Simulation and Water Quality Assessment; Section 1: California Coastal Commission's 1986 Certified Land Use Plan and Secondary Alternative

19. ABSTRACT (Continued).

To satisfy the CCC requirements for confirmation of the LUP, the SLC requested the US Army Engineer Waterways Experiment Station (WES) through a Memorandum of Agreement executed 2 July 1987 to conduct engineering studies on the technical and environmental assessment of a navigable and a non-navigable ocean entrance system, as conditionally approved in the LUP. Results of these studies will assist SLC and other parties who are formulating reports and plans for the proposed Bolsa Bay project that meet the criteria set forth in Policies 23 through 26 of the LUP. These services were provided to SLC by WES under authority of Title III of the Intergovernmental Cooperation Act of 1968. As such, resultant study products are based on specific technical expertise only and should not be inferred to indicate support or nonsupport by the US Army Corps of Engineers for either project involving a navigable or non-navigable ocean entrance or for the environmental or economic aspects of these or any other subsequent project.

The purposes of the tidal circulation computer simulation modeling task were to ascertain the hydrodynamic effects relating to the development of a proposed new navigable entrance channel to Bolsa Bay with associated marinas and wetlands enhancement (termed the Preferred Alternative by the County of Orange and the CCC), both with and without a navigable connector channel to Huntington Harbour. The effects of a non-navigable entrance channel to Bolsa Bay with associated marinas and wetlands enhancement (termed the Secondary Alternative by the County of Orange and the CCC), both with and without a by-pass channel connecting the East Garden Grove-Wintersburg Flood Control Channel with a proposed marina near existing Warner Avenue, were ascertained. Additionally, the hydrodynamic effects resulting from the closure of the Secondary Alternative non-navigable entrance channel concept by littoral material transport in the surf zone were determined. The hydrodynamic phenomena pertaining to each of these alternative concepts include tidal water surface elevation fluctuations and velocities in the Anaheim Bay complex, Huntington Harbour, Outer Bolsa Bay, Inner Bolsa Bay, the California Department of Fish and Game muted tidal cell, entrance channels, marinas, and all wetlands development proposed for enhancement and improvement of the existing biological reserves.

The purposes of the transport computer simulation and water quality assessment include assembling and synthesizing existing water quality data, and collecting supplemental water quality data, for calculating any potential changes to transport and dispersion of conservative tracers from existing conditions by proposed navigable and non-navigable entrance channels. An evaluation of the quality of the present water supply provided by existing conditions in the ecological reserve with the quality of water to be provided with the proposed navigable and non-navigable entrance channels and wetlands enhancement concept, both in terms of water quality parameters and water parcel residence times, was performed. The effects of proposed enhancements on water quality in the Anaheim Bay complex, Huntington Harbour, existing wetlands, and flushing capability of proposed wetlands modifications, also were ascertained.

The development of either a new navigable (Preferred Alternative) or non-navigable (Secondary Alternative) entrance channel system to Bolsa Bay with associated marinas, full tidal, and muted tidal wetlands enhancement is feasible from engineering, hydrodynamic, and water quality standpoints investigated by this study. The non-navigable (Secondary Alternative) entrance channel system does not adversely impact flushing of Huntington Harbour, and the overall residence times in both the full and muted tidal wetlands areas of Bolsa Bay are reduced to a greater degree than for the navigable (Preferred Alternative) entrance channel concept. Since the non-navigable entrance channel could be reopened immediately following closure by a storm, other related environmental elements such as water age may not be adversely impacted. Any potential for scour resulting from high velocities near bridges or in Outer Bolsa Bay could be prevented by channel stabilization measures provided as part of project construction. The Bolsa Bay complex will provide for multiple public and private uses with an emphasis on wildlife habitat enhancement, public recreation, coastal access, and water dependent residential development.

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PREFACE

Authority to carry out this investigation was granted the Coastal Engineering Research Center (CERC), US Army Engineer Waterways Experiment Station (WES), by a Memorandum of Agreement executed 2 July 1987 between the California State Lands Commission (SLC) and the Department of the Army under authority of Title III of the Intergovernmental Cooperation Act of 1968. As such, resultant study products are based on specific technical expertise only and should not be inferred to indicate support or nonsupport by the Corps of Engineers for the environmental or economic aspects of any subsequent project.

The study reported herein was conducted during the period October 1987 and December 1988 by Dr. Lyndell Z. Hales, Research Hydraulic Engineer, Coastal Processes Branch (CPB), Research Division (RD), CERC; Ms. Sandra L. Bird, Civil Engineer, American Scientific International (formerly Research Civil Engineer, Water Quality Modeling Group (WQMG), Ecosystem Research and Simulation Division (ERSD), Environmental Laboratory (EL), WES); Mr. Bruce A. Ebersole, Chief, CPB; and Dr. Raymond Walton, Senior Scientist, Camp Dresser & McKee International, Inc.

This investigation was performed under the general supervision of Dr. James R. Houston, Chief, CERC; Mr. Charles C. Calhoun, Jr., Assistant Chief, CERC; Mr. H. Lee Butler, Chief, RD, CERC; Dr. Stephen A. Hughes, former Chief, CPB, RD, CERC; Dr. John Harrison, Chief, EL; Dr. John W. Keeley, Assistant Chief, EL; and Mr. Mark S. Dortch, Chief, WQMG, ERSD, EL. This report was prepared by Dr. Hales, Ms. Bird, Mr. Ebersole, and Dr. Walton.

Project Managers during the conduct of this investigation and the publication of this report were Mr. Daniel Gorfain for SLC and Dr. Hughes for WES.

Commander and Director of WES during the publication of this report was COL Larry B. Fulton, EN. Technical Director of WES was Dr. Robert W. Whalin.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	0.40469446	hectares
cubic feet	0.028317	cubic metres
cubic feet per second	0.028317	cubic metres per second
cubic yards	0.7645549	cubic metres
cubic yards per year	0.7645549	cubic metres per year
Fahrenheit degrees	5/9*	Celsius degrees or kelvins
feet	0.3048	metres
feet per second	0.3048	metres per second
feet per second per second	0.3048	metres per second per second
inches	25.4	millimetres
miles (US statute)	1.609347	kilometres
nautical miles	1.853187	kilometres
pounds per cubic foot	16.01846	kilograms per cubic metre
pounds per square foot	4.88242796	kilograms per square metre
square feet	0.09290304	square metres
square feet per second	0.09290304	square metres per second

* To obtain Celsius (C) temperature readings from Fahrenheit (F) temperature readings, use the following formula: $C = (5/9)(F - 32)$. To obtain Kelvin (K) temperature readings from Fahrenheit (F) temperature readings, use the following formula: $K = (5/9)(F - 32) + 273.15$.

BOLSA BAY, CALIFORNIA, PROPOSED OCEAN ENTRANCE SYSTEM STUDY

TIDAL CIRCULATION AND TRANSPORT COMPUTER SIMULATION AND WATER QUALITY ASSESSMENT

Section 1: California Coastal Commission's 1986 Certified Land Use Plan and Secondary Alternative

PART I: INTRODUCTION

Bolsa Chica Modeling Studies

1. The State of California, State Lands Commission (SLC), is reviewing a plan for a new ocean entrance system as part of a multi-use project. This project involves both State and private property in the development proposed by the SLC, Signal Landmark, and others. The project, located in the Bolsa Chica area of the County of Orange, California, includes navigational, commercial, recreational, and residential uses, along with major wetlands restoration. The County of Orange approved a Land Use Plan (LUP) in 1985 as part of the Local Coastal Program for Bolsa Chica, in accordance with the California Coastal Act of 1976. This same LUP was certified by the California Coastal Commission (CCC) with conditions in 1986. Part of the LUP certification requirement to satisfy those conditions include confirmation review of modeling studies of a navigable and a non-navigable ocean entrance at Bolsa Chica.

2. In order to satisfy the CCC requirements for confirmation of the LUP, the SLC requested the US Army Engineer Waterways Experiment Station (WES), through a Memorandum of Agreement executed July 2, 1987, to conduct engineering studies on the technical and environmental assessment of a navigable ocean entrance system, and a non-navigable ocean entrance system, as conditionally approved in the LUP. Results of these studies will assist SLC and other parties which are formulating reports and plans for the proposed Bolsa Bay project that meet the criteria set forth in Policies 23 through 26 of the LUP. These services were provided to SLC by WES under authority of

Title III of the Intergovernmental Cooperation Act of 1968. As such, resultant study products are based on specific technical expertise only, and should not be inferred to indicate support or non-support by the Corps of Engineers for either project involving a navigable or non-navigable ocean entrance, or for the environmental or economic aspects of these or any other subsequent project.

3. Modeling studies of the Bolsa Chica area conducted by WES fall into four general categories:

- a. Numerical modeling of long-term shoreline response as influenced by placement of entrance channel stabilization structures, including sand management concepts,
- b. Physical modeling of the proposed entrance channel, interior channels, and marina with regard to wave penetration, harbor oscillation, and qualitative sediment movement paths,
- c. Numerical modeling of tidal circulation, including transport and dispersion of conservative tracers, in the Bolsa Bay, Huntington Harbour, and Anaheim Bay complex, and
- d. Potential impacts of various ocean entrance designs on the local wave climate and, consequently, the potential impacts on recreational surfing activities at the proposed ocean entrance.

4. Detailed results of the modeling studies are reported in four separate reports. The report titles and a brief description of each report scope are given below.

Report 1: Preliminary Shoreline Response Computer Simulation

5. This report describes numerical model simulations of long-term shoreline position change as a result of longshore movement of sediment. The model simulations are termed preliminary because of uncertainties associated with wave data used as input. Shoreline change simulations covering a 10-year period over the reach of coast from Anaheim entrance southward to the Santa Ana River are compared for a variety of conditions, including a non-navigable entrance, a structured navigable entrance without sand management, and a structured navigable entrance with sand management techniques. This study was conducted to determine a reasonable range of shoreline response to construction of an entrance system, and to evaluate the potential for mitigation of any adverse effects induced by the entrance. The preliminary modeling was conducted in advance of a special Coastal Commission required "Confirmation Review" hearing on the Bolsa Chica LUP, and in advance of detailed wave

hindcasts utilized during the Comprehensive Shoreline Response Computer Simulation.

Report 2: Comprehensive Shoreline Response Computer Simulation

6. This report describes numerical model simulations of long-term shoreline change under the same conditions as tested in the preliminary modeling described in Report 1. The comprehensive modeling effort utilizes hindcast wave data obtained from the Wave Information Study (WIS) of the Corps of Engineers. These hindcast data represent the best available wave data for use in the shoreline model. Partial funding of the WIS hindcast at Bolsa Chica was provided by SLC as part of the overall Bolsa Chica Study. This report also contains a stability analysis of the proposed non-navigable entrance channel.

Report 3: Tidal Circulation and Transport Computer Simulation, and Water Quality Assessment

7. This report describes numerical model simulations of tidal circulation constituent transport in the Bolsa Bay, Huntington Harbour, and Anaheim Bay complex. A link-node model was calibrated and verified using data from the present configuration of the tidally-subjected region. The calibrated numerical model was then used to simulate a variety of proposed area developments, including increased wetlands, full tidal and muted tidal areas, marinas, and navigation channels. Modeling provided results for the proposed navigable and non-navigable entrance alternatives, with and without a navigable connector channel to Huntington Harbour from Outer Bolsa Bay. Water Quality assessment is provided based on existing conditions and data, coupled with constituent transport modeling results. The transport modeling results provide estimates of water flushing and residence times which are used to project water quality parameters expected in the new wetlands configuration.

Report 4: Physical Model Simulation

8. This report describes results obtained from tests conducted in a 1-to-75 model-to-prototype scale physical model of the proposed Bolsa Bay entrance channel and marina complex. The purpose of the testing was to examine wave penetration into the marina basin and the resulting harbor oscillations, to qualitatively study current circulation and sediment transport paths in the vicinity of the structures, and to make preliminary assessment of the entrance channel design configuration. Physical model inputs included

unidirectional irregular waves, steady-state flood and ebb tidal currents, and flood flows from the East Garden Grove-Wintersburg Flood Control Channel.

Purpose of the Study

Tidal circulation computer simulation

9. The purposes of the tidal circulation computer simulation modeling task were to ascertain the hydrodynamic effects relating to the development of a proposed new navigable entrance channel to Bolsa Bay with associated marinas and wetland enhancement (termed the Preferred Alternative by the County of Orange and the California Coastal Commission), both with and without a navigable connector channel to Huntington Harbour. The effects of a non-navigable entrance channel to Bolsa Bay with associated marinas and wetland enhancement (termed the Secondary Alternative by the County of Orange and the California Coastal Commission), both with and without a non-navigable channel connecting the East Garden Grove-Wintersburg Flood Control Channel with a proposed marina near existing Warner Avenue, were ascertained. Additionally, the hydrodynamic effects resulting from the closure of the secondary alternative non-navigable entrance channel concept by littoral material transport in the surf zone were determined. The hydrodynamic phenomena pertaining to each of these alternative concepts include tidal water surface elevation fluctuations and velocities in the Anaheim Bay complex, Huntington Harbour, Outer Bolsa Bay, Inner Bolsa Bay, the California Department of Fish and Game (DFG) muted tidal cell, entrance channels, marinas, and all wetland development proposed for enhancement and improvement of the existing biological reserves.

Transport computer simulation and water quality assessment

10. The purposes of the transport computer simulation and water quality assessment included assembling and synthesizing existing water quality data, and collecting supplemental water quality data, for calculating any potential changes to transport and dispersion of conservative tracers from existing conditions by proposed navigable and non-navigable entrance channels. An evaluation of the quality of the present water supply provided by existing conditions in the ecological reserve with the quality of water to be provided with the proposed navigable and non-navigable entrance channels and wetland enhancement concepts, both in terms of water quality parameters and water

parcel residence times, was performed. The effects of proposed enhancements on water quality in the Anaheim Bay complex, Huntington Harbour, existing wetlands, and flushing capability of proposed wetland modifications, were ascertained.

Scope of the Investigation

Tidal circulation computer simulation

11. The evaluation of the effects of construction of a new navigable or non-navigable entrance channel to Bolsa Bay, and the effects of wetlands restoration plans, were investigated by the application of a tidal circulation hydrodynamic model DYNamic TRANsport (DYNTRAN). Several hydrodynamic models were available (i.e., finite difference, finite element, link node, etc.) for application to the inlet-bay system. The specific model choice was determined by the characteristics of the channelized Anaheim Bay, Huntington Harbour, and Outer Bolsa Bay regions, and by the requirements of the water quality modeling effort. Basic features of the model include inundation of low-lying terrain, treatment of subgrid barrier effects, and utilization of actual bathymetry with spatially-variable bottom roughness.

12. Prototype field data were required to calibrate and verify the numerical model. Synoptic data for calibration and verification included simultaneous water surface elevations, tidal current velocities, and phase differences obtained at a finite number of station locations in the Bolsa Bay complex, and at specific station locations along the connecting channels through Huntington Harbour complex and Anaheim Bay. The model was calibrated with one set of prototype field data, and then verified by reproducing an entirely different set of prototype field data. Numerical model tidal circulation results were obtained for both navigable and non-navigable entrance channel concepts, and for evaluated plan concepts pertaining to connecting channel modifications, interior channels, and marina configurations. Test conditions included neap tide, mean tide, and spring tide. Model results included comparisons of tidal elevations and currents for each plan with those for existing conditions. Results of this tidal circulation task were utilized as input data for the water quality modeling task, and the physical hydraulic modeling task.

Transport computer simulation and water quality assessment

13. Existing data and information pertaining to water quality characteristics of Bolsa Bay were assembled and analyzed. Existing information was obtained from all Federal, State, and Local agencies, and other private groups or organizations concerned with the water quality of the Bay. Deficiencies in the existing data base were determined, and supplemental field data were procured for obtaining additional knowledge to provide an understanding of the current water quality conditions of the Bolsa Bay study area. Data acquisition consisted of field measurements of temperature, pH, conductivity, and dissolved oxygen. A limited sediment sampling effort to determine any contamination in the existing wetlands was performed.

14. The existing water quality data of the Bolsa Bay complex, and the supplemental data collected during the field data acquisition program, were analyzed and evaluated by DYNTRAN to determine the present state of water quality throughout the area of interest. This was performed so that preservation and enhancement will be accomplished. An integrated compartment numerical model driven by output results from the tidal circulation hydrodynamic modeling was adapted to the Bolsa Bay complex for calculating transport and dispersion of conservative tracers throughout the Bay complex and enhanced wetland areas, for both the navigable and non-navigable entrance channel concepts. Ocean regions are considered hydrodynamic boundaries.

Alternative concepts evaluated

15. Twelve different variations of the two basic plans were evaluated.

Code	Entrance Channel	Connector Channel to Huntington Harbour	Wetlands Connected	Connector Channel to Marina
NENC1	Navigable	Navigable	Yes	---
NENC2	Navigable	Navigable	No	---
NENNC1	Navigable	Non-Navigable	Yes	---
NENNC2	Navigable	Non-Navigable	No	---
NNECC1	Non-Navigable	Non-Navigable	No	Yes
NNECC2	Non-Navigable	Non-Navigable	No	No
NNECC3	Non-Navigable	Non-Navigable	Yes	Yes
NNECC4	Non-Navigable	Non-Navigable	Yes	No
NOENT1	Closed	Non-Navigable	No	Yes
NOENT2	Closed	Non-Navigable	No	No
NOENT3	Closed	Non-Navigable	Yes	No
NOENT4	Closed	Non-Navigable	Yes	Yes

PART II: BACKGROUND

Description of the Bolsa Chica Area

16. Bolsa Chica is an unincorporated area of Orange County, California, located along the coastline approximately 9 miles* south of Long Beach, and surrounded by the City of Huntington Beach (Figure 1). The Bolsa Chica project area (Figure 2) comprises approximately 1,645 acres, which includes the Bolsa Mesa and adjacent lowlands, and the shoreline adjacent to the bay from the intersection of Warner Avenue and the Pacific Coast Highway (PCH) to the Huntington Mesa, located to the north of the intersection of Golden West Boulevard and the PCH. As discussed by the US Army Engineer District, Los Angeles (1987), the project area is bordered by bluffs on the northwest and southeast, and by the Pacific Coast Highway and Bolsa Chica Beach State Park on the southwest. Urban lands lie north and east of the project area.

17. The Bolsa lowland area is a remnant of a once-extensive tidal and river wetlands system of the mouth of the Santa Ana River which extended inland across the coastal plain to the surrounding mountains. Historically, the lowlands were frequently inundated by tidal flows through a direct natural connection to the ocean, and received fresh water from artesian wells and from local storm-water runoff. In 1899 tidal flow into the Bolsa Chica area was modified by construction of tide gates, and the natural channel to the ocean was eventually closed. The Bolsa Chica area was further modified in the 1920s by oil and gas interests, and construction of PCH. Subsequently, construction of the East Garden Grove-Wintersburg Flood Control Channel bisected the area, and its flow discharged into Outer Bolsa Bay and then into Huntington Harbour.

18. At present, tidal flow enters Outer Bolsa Bay and Inner Bolsa Bay (Figure 3) only through Huntington Harbour and Anaheim Bay. Local runoff and precipitation provide the freshwater inflow. Dirt roads and dikes criss-cross the lowland connecting drill pads, oil pumping rigs, related structures, and pipe networks. Other existing improvements include the East Garden Grove-Wintersburg Flood Control Channel, bridges that cross the channel, tide gates at the confluence of the flood control channel and Outer Bolsa Bay, and a

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* A table of factors for converting non-SI units of measurements to SI (metric) units is presented on page 6.

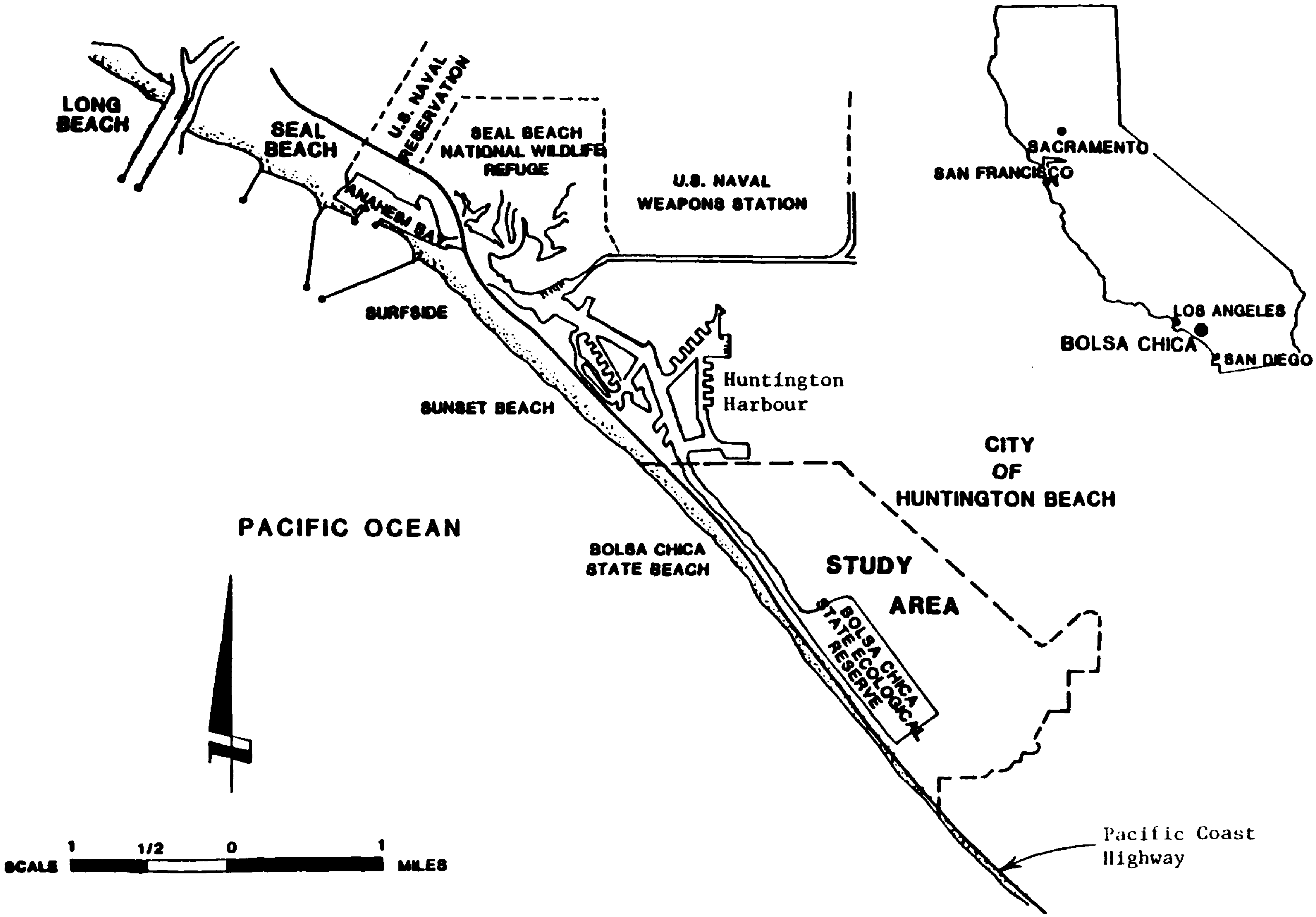


Figure 1. Bolsa Chica, California, study region location (after Orange County Environmental Management Agency 1985)

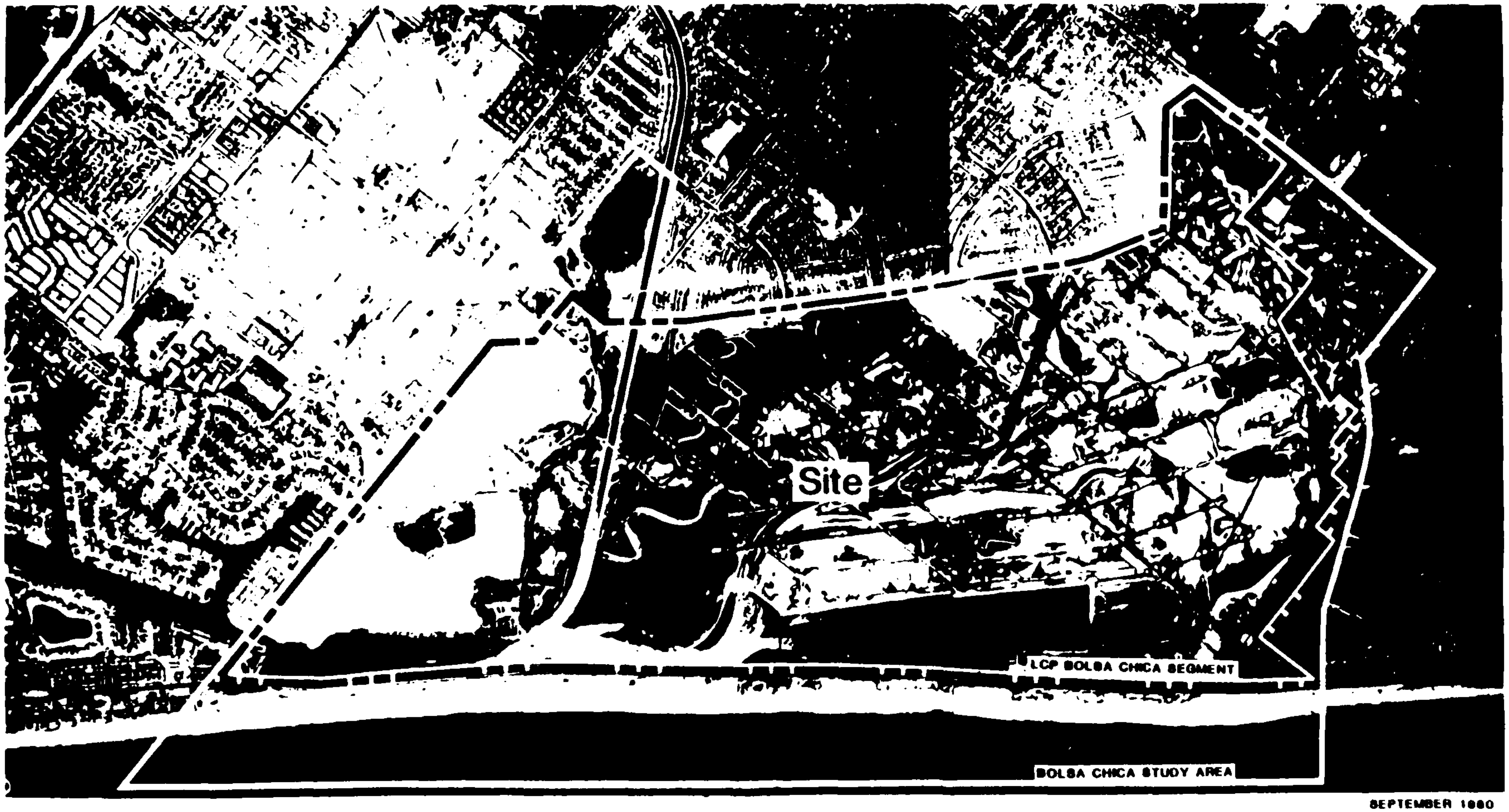


Figure 2. Bolsa Chica, California, area of interest
(after Orange County Environmental Management Agency 1985)

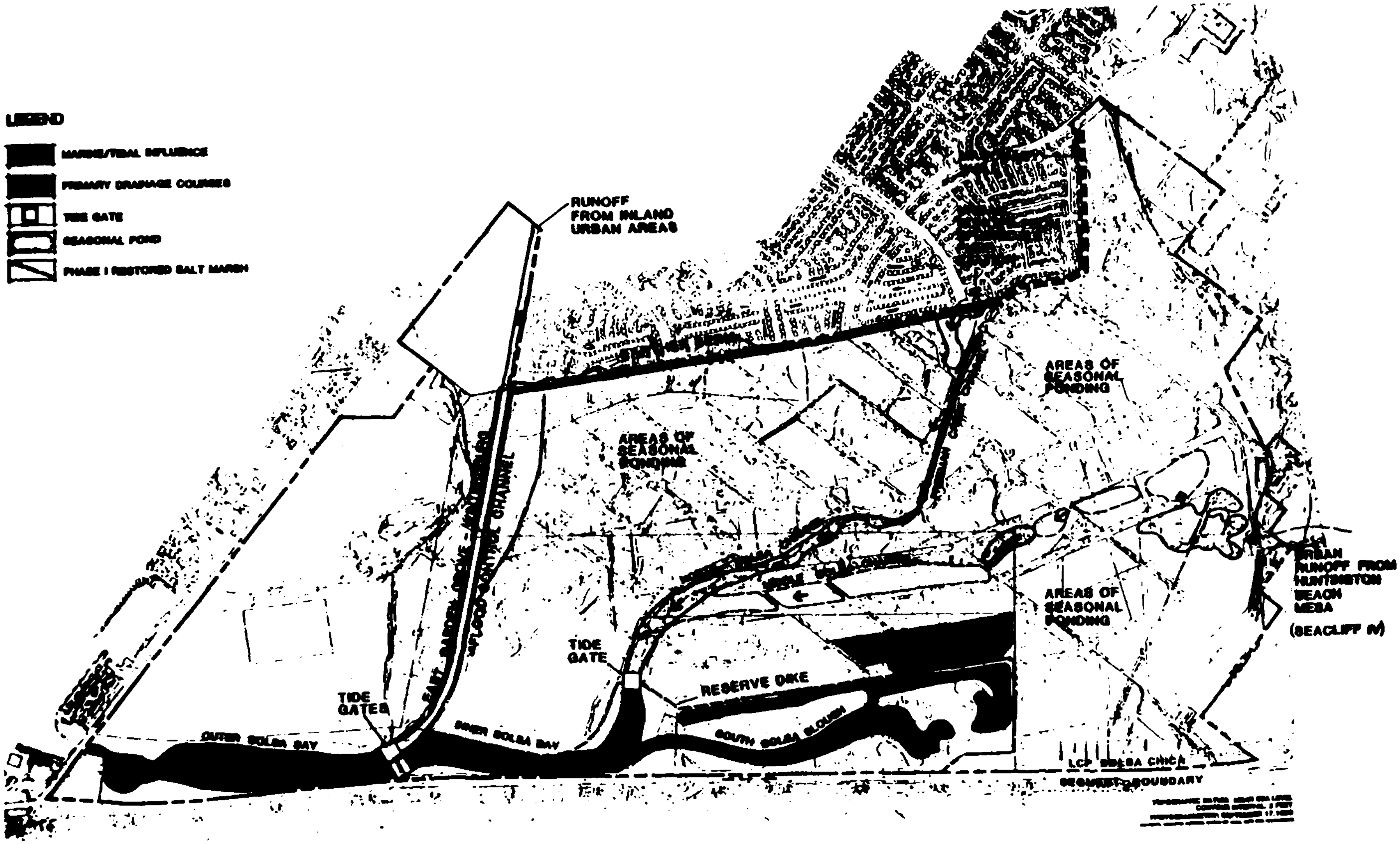


Figure 3. Present tidal inundation, Bolsa Chica, California (after Orange County Environmental Management Agency 1985)

pedestrian walkway and footpath to the Bolsa Chica State Ecological Reserve from a public parking lot adjacent to PCH.

19. The community surrounding Bolsa Chica (the City of Huntington Beach), is predominantly a medium-density residential community. Bolsa Chica State Beach, on the ocean side of Bolsa Chica across the PCH, is utilized by both residents and visitors from outside the area. Recreational beach uses include sunbathing, swimming, picnicking, surfing, and hiking and bicycling along trails located along the seaward side of the beach parking areas. There is also a private equestrian facility with training facilities located in the northerly corner of the lowland. Recreational boating opportunities in the immediate area are located in the marina at Huntington Harbour, with ocean access being provided by the entrance to Anaheim Bay.

20. A 300-acre State-owned Ecological Reserve, of which 173 acres have been restored to high quality wetlands habitats, contains a limited amount of public footpaths for nature study. Public access into the majority of the Reserve is restricted to preclude unnecessary disruptions to wildlife values and use. An additional 230 acres adjacent to the Reserve is leased to the State of California by the major landowner of the area, Signal Landmark (Figure 4). These lands would be conveyed to the State provided that the State causes the construction of a navigable ocean entrance and channel connecting to Signal lands, as part of the Bolsa Chica Land Use Plan. The Bolsa Chica lowland and existing wetlands in the Reserve provide important habitat both for migratory birds which nest, rest, and/or feed in the area, as well as resident shorebirds, waterfowl, and other vertebrate and invertebrate wildlife.

21. The County of Orange has adopted a Land Use Plan for the Bolsa Chica Project pursuant to State requirements under the California Coastal Act of 1976. The plan was certified by the Coastal Commission in January 1986, subject to review and confirmation of five elements. The certified Land Use Plan contains both urban and wildlife uses that yield more than 75 percent of the area as public use and other public open space. This certified Land Use Plan includes 915 acres of existing and restored wetlands, 86.8 acres of additional environmentally sensitive habitats, a 1300-slip public marina with land provided for an additional 400 dry-stored boats, public launch ramps, and commercial areas providing visitor-serving uses and amenities. More than

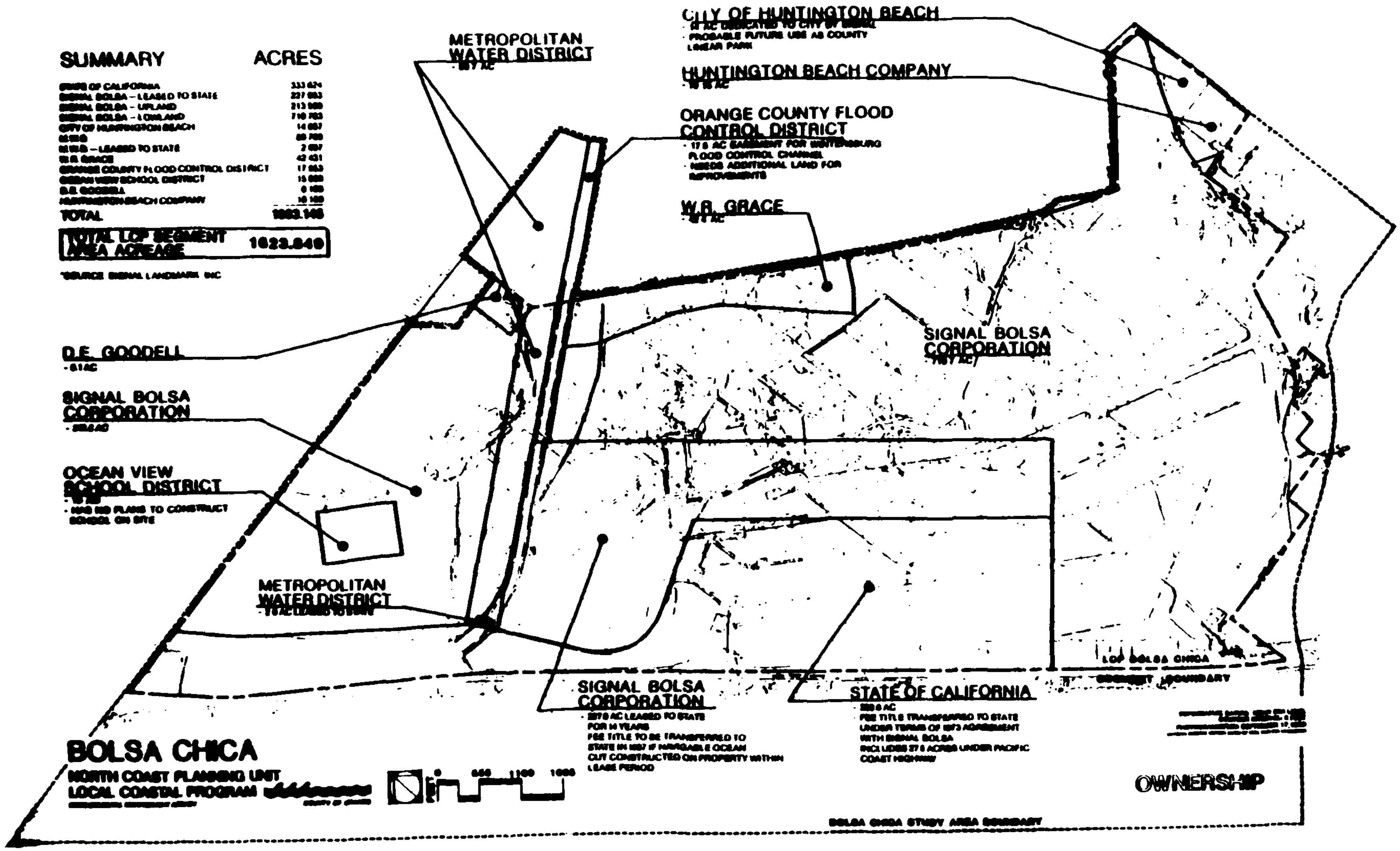


Figure 4. Land ownership, Bolsa Chica, California, region (after Orange County Environmental Management Agency 1985)

100 acres of navigable waters also are proposed to serve the marina-commercial complex, and to provide delivery of ocean waters to the restored wetlands areas. Flood control improvements, new public roads, hiking, bicycling and equestrian trails, public parks, and other major infrastructure also are planned. Finally, the Plan will contain residential uses, including waterfront and off-water dwelling units.

Historical Perspective

22. Involvement of the Federal government in the Bolsa Chica region was directed by Congressional resolutions in 1964 and 1976, and reaffirmed by the Water Resources Development Acts of 1986 and 1988. (The use of the phrase "Sunset Harbor" in those authorizing documents is incorrect, as no such location exists.) The 1964 resolution requested a study to determine the need for a light-draft vessel harbor at Bolsa Chica. The 1976 resolution expanded the study scope to include determination of the feasibility and desirability of providing and maintaining tidal waters and re-creating a tidal marsh. Several studies and surveys have been conducted by both the US Army Engineer District, Los Angeles (SPL), and non-Corps interests. In addition, a Corps feasibility study had been initiated in response to the 1976 Congressional authority, but has not been completed at the present time.

Congressional Resolution of 1964

23. This resolution, requested by Congressman Richard T. Hanna and adopted April 11, 1964, states:

> "...Resolved by the Committee on Public Works of the House of Representatives, United States, that the Board of Engineers for Rivers and Harbors is hereby requested to review the reports on the coast of southern California, with a view to determining the need for a harbor for light-draft vessels in the Bolsa Chica-Sunset Bay area, California..."

Congressional Resolution of 1976

24. This resolution, requested by Congressman Mark W. Hannaford and adopted September 23, 1976, states:

> "...Resolved by the Committee on Public Works and Transportation of the House of Representatives, United States, that the Board of Engineers for Rivers and Harbors is hereby requested to review the reports on the Coast of Southern California for Light Draft Vessels with a view to determining whether any modifications therein are

warranted in the Bolsa Chica-Sunset Bay area, California, and to conduct a study to determine the feasibility and desirability of re-creating a tidal marsh upon the State-controlled lands in Bolsa Chica Bay for increasing its value for fish and wildlife. This study is to include evaluation and investigation of levees, jetties, breakwaters, and other works needed to provide and maintain tidal waters within the proposed marsh..."

Water Resources Development Act of 1986 (PL 99-662)

25. The following excerpt from the Water Resources Development Act of 1986 pertains to the Bolsa Chica area, although the Corps has not at present interpreted pertinent sections of the Act, nor determined how best to implement such sections thereof:

SEC. 1119: SUNSET HARBOR, CALIFORNIA

a. "...The Secretary is directed to expedite completion of the feasibility study of the navigation project for Sunset Harbor, California,...and to submit a report to Congress on the results of such study...

b. ...Upon execution of agreements by the State of California or Local sponsors, or both, for preservation and mitigation of wetlands areas and appropriate financial participation, the Secretary is authorized to participate with appropriate non-Federal sponsors in a project to demonstrate the feasibility of non-Federal cost sharing under provisions of Section 916 of this Act..."

26. Any and all provisions of the Water Resources Development Act of 1986 (PL 99-662) should be read with the understanding that the Department of the Army has not, at present, made any determination or interpretation with respect to this Act.

Water Resources Development Act of 1988 (PL 100-676)

27. The following excerpt from the Water Resources Development Act of 1988 pertains to the Bolsa Chica area.

SEC. 4: SUNSET HARBOR, CALIFORNIA

f. "...The demonstration project at Sunset Harbor, California, authorized by Sec. 1119(b) of the Water Resources Development Act of 1986 (100 Stat. 4238), is modified to include wetland restoration as a purpose of such demonstration project. All costs allocated to such wetland restorations shall be paid by non-Federal interests in accordance with Sec. 916 of such Act..."

Settlement Agreement of 1973

28. During preparation of this report, Signal Landmark was the major landowner in the Bolsa Chica study area, having title to 1,200 acres.

W. R. Grace Properties, Inc. owned 42 acres adjacent to the East Garden Grove-Wintersburg Flood Control Channel and the northerly boundary of the site. Slightly more than 100 acres were owned by other interests which include the Metropolitan Water District of Southern California, the Huntington Beach Company, the Ocean View School District, and Donald Goodell. The State of California holds title to 327.5 acres in addition to 230 acres that it holds pursuant to a lease with an option to acquire, subject to the provisions of the 1973 "Boundary Settlement and Land Exchange Agreement Regarding Lands in the Bolsa Chica Area, Orange County, California."

29. Under the 1973 Settlement Agreement between the State and Signal Landmark, which was signed by the governor of California on March 15, 1973, the State acquired title to a 327.5-acre parcel in the Bolsa Chica lowland. The State also acquired a lease for an additional 230 acres adjacent to the 327.5-acre parcel for a period of 14 years, which was extended to 17 years by the parties in 1984. The State has an option to acquire title to the 230-acre lease parcel if (among other conditions) a navigable ocean entrance system is constructed within a specified time period. Such a system is to consist of a navigable waterway between the Pacific Ocean and land owned by Signal Landmark in the Bolsa Chica area.

Proposed Improvements

30. The County of Orange has adopted a Land Use Plan (LUP) as part of the Local Coastal Program for the Bolsa Chica area in accordance with the California Coastal Act of 1976. This LUP includes a navigable ocean entrance system (Preferred Alternative), and a non-navigable ocean entrance system (Secondary Alternative). The principal landowner of the region, Signal Landmark, desires to implement the Preferred Alternative.

Preferred Alternative

31. The Preferred Alternative of the LUP, as depicted in Figure 5, contains the following features and acreage allocations:

a. 915 acres of restored, high quality, fully-functioning full tidal, muted tidal, fresh, and brackish water wetlands within the study area, with emphasis on diversity of habitat and protection and recovery of endangered species,

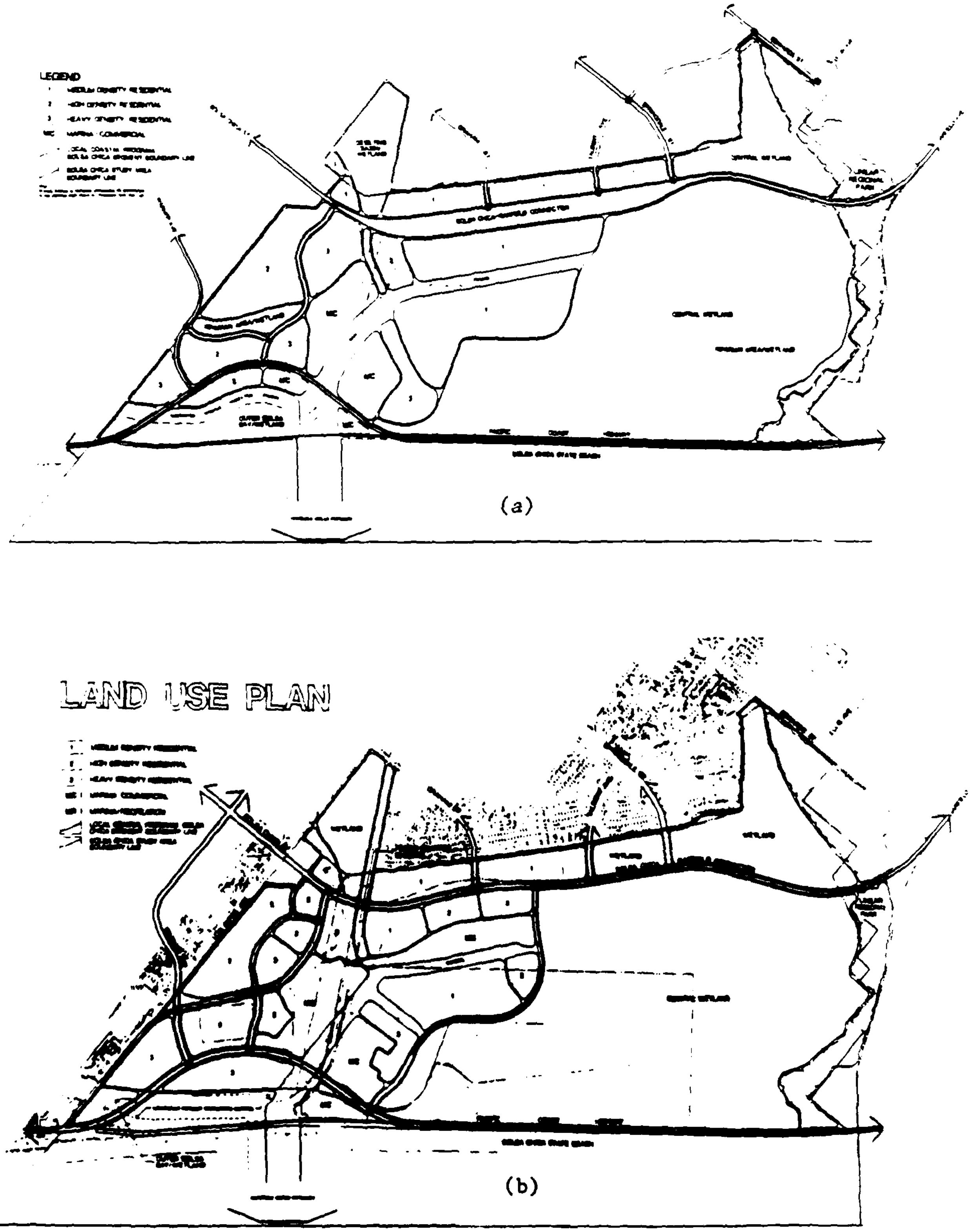


Figure 5. *Bolsa Bay* Preferred Alternative;
(a) adopted land use plan, and (b) revised land use plan

b. 86 acres of existing or newly created environmentally sensitive habitat within the study area,

c. Buffer areas between wetlands and urban development to protect environmentally sensitive habitats,

d. A fully-navigable ocean entrance to provide a continuous, assured source of water for tidal wetlands and interior water ways, and for recreational boating ocean access from both the Bolsa Chica area and Huntington Harbour,

e. Interior navigable waterways providing navigable connections to the Bolsa Bay marina, waterfront residential housing, and Huntington Harbour,

f. At least 75 acres of mixed-use, marina and commercial area providing in-water berthing and dry storage for at least 1,700 boats,

g. A realignment of the Pacific Coast Highway (PCH) from the existing PCH-Warner Avenue intersection, across Outer Bolsa Bay, Bolsa Chica Mesa, and the main entrance channel to the proposed marina,

h. An internal roadway system connecting Bolsa Chica Street with Garfield Avenue within a corridor between 500 and 950 ft from adjacent existing neighborhoods,

i. Creation of a 130-acre Bolsa Chica Linear Regional Park on Huntington Mesa, and

j. Approximately 500 gross acres of medium-, high-, and heavy-density residential development in the lowland and on Bolsa Chica Mesa.

__Secondary Alternative__

32. In certifying the LUP, the California Coastal Commission (CCC) also cei ified an alternative plan (Secondary Alternative), shown in Figure 6, with a non-navigable ocean entrance and different internal use configurations than the Preferred Alternative. This alternative contains 915 acres of wetlands, a non-navigable ocean entrance, and a marina along the present Warner Avenue alignment on Bolsa Chica Mesa. The CCC indicated that the Secondary Alternative could be certified as the LUP without further hearings if the proposed navigable ocean entrance were found to be infeasible pursuant to performance standards contained in the November 1984 staff report and the January 1986 certified LUP, and if the Secondary Alternative were adopted by the County of Orange as its Land Use Plan.

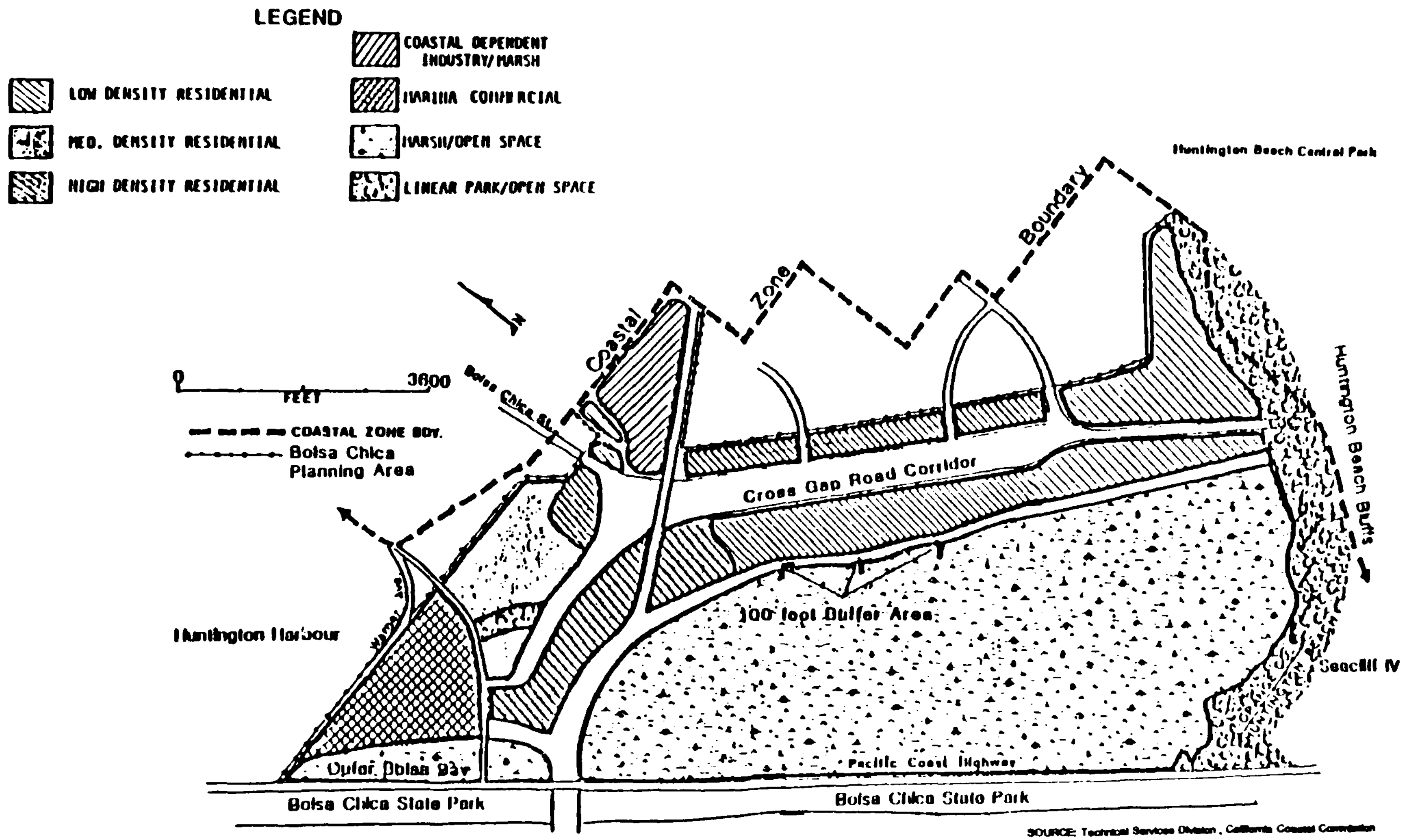


Figure 6. Bolsa Bay Secondary Alternative
(after Orange County Environmental Management Agency 1985)

Previous Studies

33. The Bolsa Chica area is located immediately adjacent to Huntington Harbour, from which navigation vessels exit to the Pacific Ocean through Anaheim Bay. The Anaheim Bay entrance is heavily utilized by Seal Beach Naval Weapons Station, and concern has existed for many years about accidental encounters between civilian and military craft in this area, where ammunition off-loading and storage are common practices. Local interests have previously requested the US Army Engineer District, Los Angeles, to investigate the practicality of the construction of a new entrance channel connecting Bolsa Chica with the Pacific Ocean.

34. The Bolsa Chica and Huntington Harbour regions are separated from the Pacific Ocean by Surfside, Sunset Beach, and Bolsa Chica State Beach. The west jetty at Anaheim Bay effectively creates a littoral cell boundary at Seal Beach for the region of coast to the north, and the east jetty is a boundary for the littoral cell between the Anaheim jetties and Newport to the south. Rivers no longer contribute significant sediment into the littoral cell between Anaheim and Newport Beach. Artificial beach nourishment at Surfside-Sunset, in amounts that average approximately 350,000 cu yd per year, has provided a feeder beach for the littoral cell that extends down the coast toward Newport Beach. Much of the nourishment is due to disposal of material excavated from the Navy channel at Anaheim and has been dictated by funds available, rather than by the optimum requirements for beach nourishment.

35. A new entrance channel to Bolsa Chica will require stabilization by a jetty system. Furthermore, interruption of downcoast movement of littoral material may require a sand bypassing system. Tidal flow through a new entrance channel also may affect tidal circulation through Huntington Harbour. These concerns are multifaceted and interrelated, and have given rise to many studies of beach processes and tidal circulation evaluations in recent years.

State of California studies

36. Following completion of the boundary settlement and land exchange agreement between the State of California and Signal Landmark, it became apparent that a plan should be developed depicting the interests of all concerned State agencies. The 1973 State budget provided funds for such a planning effort involving the Departments of Transportation, Fish and Game, Parks

and Recreation, and the Department of Navigation and Ocean Development. That plan, entitled "Bolsa Chica Marsh Re-Establishment Project" (State of California, 1974), was presented by The Resources Agency. Alternative methods were evaluated for obtaining the greatest benefits for the use of public lands in Bolsa Chica and fulfilling the land settlement commitments. Each alternative included the following:

- a. Development of an additional area to provide a total of approximately 350 acres of marsh,
- b. Construction of interpretive and visitor-use facilities,
- c. Construction of a channel to the ocean to provide tidal waters to the marsh and ocean access for boats,
- d. Construction of an 1800-boat marina and small boat launching ramp,
- e. Provisions for a 300-ft wide channel connection between Signal properties and State lands,
- f. Integrated development between Bolsa Chica State Beach and the marina-ecological reserve complex, and
- g. Transportation alternatives for the beach-marina-marsh complex.

Orange County studies

37. In addition to continuous water quality monitoring studies, the "Bolsa Chica Local Coastal Program Land Use Plan" was adopted by the Orange County Environmental Management Agency (1985), and it contains all suggested modifications approved by the CCC on October 23, 1985. These modifications have received the full concurrence of the major landowner, Signal Landmark. The wetlands concept plan has been reviewed by the California Department of Fish and Game (DFG), and is presently in the process of acceptance by DFG. The LUP includes the following features:

- a. 915 acres of productive and diverse wetlands and 86 acres of environmentally sensitive habitat areas,
- b. A navigable ocean entrance to provide high-quality tidal flow to the wetlands and navigable access to the ocean, new navigable waterways, a 75-acre or larger marina and commercial area with berthing and dry storage for at least 1,700 boats, launch ramps, and coastal-dependent, visitor-serving commercial facilities, and
- c. An optional navigable interior waterway connection to Huntington Harbour.

US Army Engineer District, Los Angeles, studies

38. The Corps study of the Bolsa Chica/Sunset Bay area, California, was authorized by Congressional resolutions in 1964 and 1976, and reaffirmed in the Water Resources Development Acts of 1986 and 1988. Several studies and surveys have been initiated, but a Corps feasibility study in response to the study authority has not been completed at the present time. Preliminary studies, and current indications of the desirability for both recreational boating and wetland restoration within the local community, suggest that achievement of both may be feasible. However, additional study is needed to determine (a) the engineering, economic, and environmental feasibility of specific plans for small-craft harbor development, and wetland preservation, enhancement, and restoration, and (b) the extent of Federal participation, if any, in any plan implementation.

Previous tidal circulation studies

39. Waterways Experiment Station (1981). The first hydrodynamic modeling of the tidal circulation characteristics of existing Bolsa Chica tidal areas was conducted for SPL by WES in 1981 to compare tidal elevations, velocities, and volumes of flow at specific prototype gage locations in Anaheim Bay, Huntington Harbour, Warner Avenue Bridge, Outer Bolsa Bay, and Inner Bolsa Bay (US Army Engineer Waterways Experiment Station 1981). The hydrodynamic model used in this study was a two-dimensional, depth-averaged, finite-difference approximation model developed at WES. Comparisons were made for existing conditions and seven proposed alternative plans. Prototype field data for numerical model calibration and comparison with alternatives had been obtained by Meridian Ocean Systems, Inc., at data stations during a 25-hr period over April 24-25, 1980. The primary objective of the study was to identify any impacts to the existing channel system in Huntington Harbour resulting from a new ocean entrance, marina, and wetland areas in Bolsa Chica. The tidal characteristics of the existing wetlands and new wetlands under the proposed plans, however, were not considered in that study. The conclusion reached from the study was that tidal amplitudes were not significantly altered in Anaheim Bay, Huntington Harbour, or Outer Bolsa Bay by any of the plans evaluated. Direction of flood flow under Warner Avenue Bridge with the proposed new entrance channel in place changed flow direction such that flood flow was into Huntington Harbour. Hence, a region of reduced tidal velocity

was indicated in Huntington Harbour.

40. Philip Williams & Associates (1984). A study of the tidal characteristics of the existing Huntington Harbour area and seven proposed alternative designs for Bolsa Chica, and an evaluation of a self-maintained ocean entrance at Bolsa Chica, were conducted by Philip Williams & Associates (1984). Because of the significant channelization throughout the flow system, this study utilized a one-dimensional link-node model that uses the method of characteristics to solve the equations of water motion within each link. Field data previously obtained by Meridian Ocean Systems, Inc., during a 25-hr period over April 24-25, 1980, were also used in this study for calibration and comparison of results. The purpose of the study was to evaluate the impacts of proposed plans on tidal velocities in Huntington Harbour, and to determine the tidal range in the restored wetland. The study concluded that, for the case of no new ocean entrance, tidal velocities in Huntington Harbour would increase with the addition of fully tidal wetlands in Bolsa Chica. With a new ocean entrance, however, the velocities would not generally increase. The analysis of tidal range in the restored wetlands consisted of a qualitative comparison between simulated conditions with and without the new ocean entrance. The results from the analysis indicated that a small dampening and phase lag would occur to the tide in Bolsa Chica if the area were opened to full tidal action with no new ocean entrance. A maximum reduction in tidal range of about 25 percent would occur during very high spring tides. These studies also concluded that proposed restoration designs for Bolsa Chica would have sufficient tidal prism to maintain a natural channel of between 1,400 and 3,700 sq ft, if the channel sides were stabilized. The channel could have widths of 200 to 450 ft, with depths from 10 to 12 ft.

41. Moffatt & Nichol, Engineers (1987). A hydraulic analysis of the Bolsa Chica wetlands was performed by Moffatt & Nichol, Engineers (1987) using a one-dimensional link-node model that was calibrated to existing conditions using field measurements taken over a 3-week period from August 16 through September 5, 1986. The study was performed to:

a. Provide an understanding of the hydraulic response of coastal wetlands, and wetlands with a muted tide regime that is applicable to Bolsa Chica wetlands,

b. Model the hydraulics of the existing Bolsa Chica wetlands and the tidal cell added by the California Department of Fish and Game, and

c. Develop a wetland model that is calibrated to existing conditions, and that can be used to analyze proposed wetland configurations.

The scope of the work required that the study:

a. Describe the hydraulics of coastal wetlands as well as tide control structures that are applicable to Bolsa Chica,

b. Outline the design approach used in the hydraulic analysis of wetlands,

c. Modify and calibrate a numerical model to analyze the existing conditions in the Bolsa Chica wetlands, and

d. Perform a sensitivity analysis to identify the relative effect that each input value has on the results in order to indicate confidence intervals.

42. The calibrated model will be used to further analyze proposed wetland configurations for Bolsa Chica. Since results obtained for proposed configurations cannot be compared with measurements to assess accuracy, a sensitivity analysis was performed to estimate the range in which the results are most likely to fall. It was determined by this study that tide range in the wetlands is greatly affected by the type of tide control structure used. Tide control structures can be designed to provide the required tidal range and mean water level in the wetlands. This is important to achieve the desired mix of habitats. The hydraulic design comprises a large part of the wetland design. The complex calculations involved are readily solved by this numerical model in a timely and economical fashion.

Previous beach sand movement studies

43. Beach Erosion Board (1956). The Anaheim Bay jetties were completed in 1944 and serve as an effective barrier to littoral sand transport along the shore to a depth of about 20 ft. The construction of the jetties was followed by severe erosion of the beach immediately to the south of the east jetty. The eroded sand was apparently transported in a southerly direction by the dominant wave action. Erosion progressed to such a degree that extensive property damage was imminent and, late in 1947, a beach fill was placed to restore the shore. (Subsequently, this reach of shoreline has been periodically renourished with an average annual volume of approximately 350,000 cu yd of sand made available from channel maintenance operations at Anaheim). Sand

movement along the coast was correlated with dominant wave energy by this study (Caldwell 1956).

44. US Army Engineer District, Los Angeles (1978). Because of the continuing necessity to rehabilitate the Surfside-Sunset Beach region of coastline due to severe beach erosion, SPL established a monitoring program to evaluate the effectiveness of the placement procedures. One of the purposes of the effort was to determine if portions of the material disappearing from the beach was moving offshore where it would be recycled periodically to the beach. Results of the overall monitoring program were inconclusive.

45. Waterways Experiment Station (1984). The potential effects of a new entrance channel to Bolsa Chica on unstabilized adjacent shorelines was considered by WES in 1984 (Hales 1984). That study utilized a one-line numerical model for longshore sediment transport and an equivalent monthly wave climate deduced from frequency of occurrence of waves from a 3-year hindcast (1956 to 1958) by National Marine Consultants (1960) and Marine Advisors (1961). Evaluations were performed for uniform bypassing placement distributions of 300, 500, 1,000, and 2,000 ft from the east jetty at Anaheim Bay. As the distribution of the bypassed material was extended farther down coast, those computational cells nearer the east jetty experienced an increased depletion of material. The actual equilibrium shoreline orientation that develops will be in response to the effectiveness of the bypassing program and the actual wave climate.

Regional Geology

46. As discussed in House Document No. 349 (US Congress 1954), Bolsa Chica is on the edge of San Pedro Bay, approximately in the center of the Los Angeles coastal plain. This low plain is bordered on the north by the eastern Santa Monica Mountains and the Repetto Hills, on the east by the Puente Hills and the Santa Ana Mountains, on the southeast by the San Joaquin Hills, and on the south and west by the Pacific Ocean. Many of the structural features surrounding the Los Angeles coastal plain are extremely young, and the present relief and alignment of geographic units are, to a large extent, the product of a mountain-building epoch. The gently curving arc of shoreline extending from Point Fermin on the west to the bluffs of Corona del Mar on the east is

composed, in part, of disconnected stretches of barrier beach fronting slowly rising tidal marsh areas. Separating these lowlands are the friable wave-cut cliffs or bluffs at Long Beach, Seal Beach, Huntington Beach, and Newport Beach. The character of these wave-cut bluffs, and the uniform plain to which they have been shaped by the sea, indicate that each headland formerly extended seaward of the present shoreline.

47. Under natural conditions that existed over 100 years ago, the Los Angeles and San Gabriel Rivers deposited most of their sediment loads on the ocean bars at their mouths where this material became available for nourishment of the beaches. Flood-control structures in the upper reaches of these rivers, constructed during the past century, now have nearly eliminated sediment from being delivered to the beaches by the rivers.

48. The significant findings resulting from a review of the geologic history of the area under investigation may be summarized as follows:

a. Prior to historic time, uplift and erosion of the headlands, together with subsidence and fill of low area, developed the early shoreline into a semblance of the present shore,

b. The shoreline appears to have become relatively stable at about the beginning of historic time, and further erosion of the headlands was dependant on the balance between losses of beach material by marine erosion and wind, and the periodic supply of new material brought to the shore by streams, and

c. During historic time, the beaches adjacent to Long Beach, Seal Beach, and Huntington Beach bluffs have remained comparatively narrow, which indicates that a very close balance between loss and supply existed in these areas.

Subsidence in the Bolsa Chica Area

49. The Local Coastal Plan has identified ground subsidence as one of the geologic hazards that must be addressed in planning the Bolsa Chica development. Subsidence in the Bolsa Chica area has been evaluated by Woodward-Clyde Consultants (1984, 1986). Subsidence refers to broad scale, gradual downward changes in elevation of the land surface. Such subsidence can occur naturally and from influences by man. The natural causes could be tectonic structural flexure of faulting, consolidation of sedimentary rocks, or highly compressible peat deposits. Man-induced subsidence has been attributed to oil and water withdrawal in many of California's oil fields and

ground-water basins.

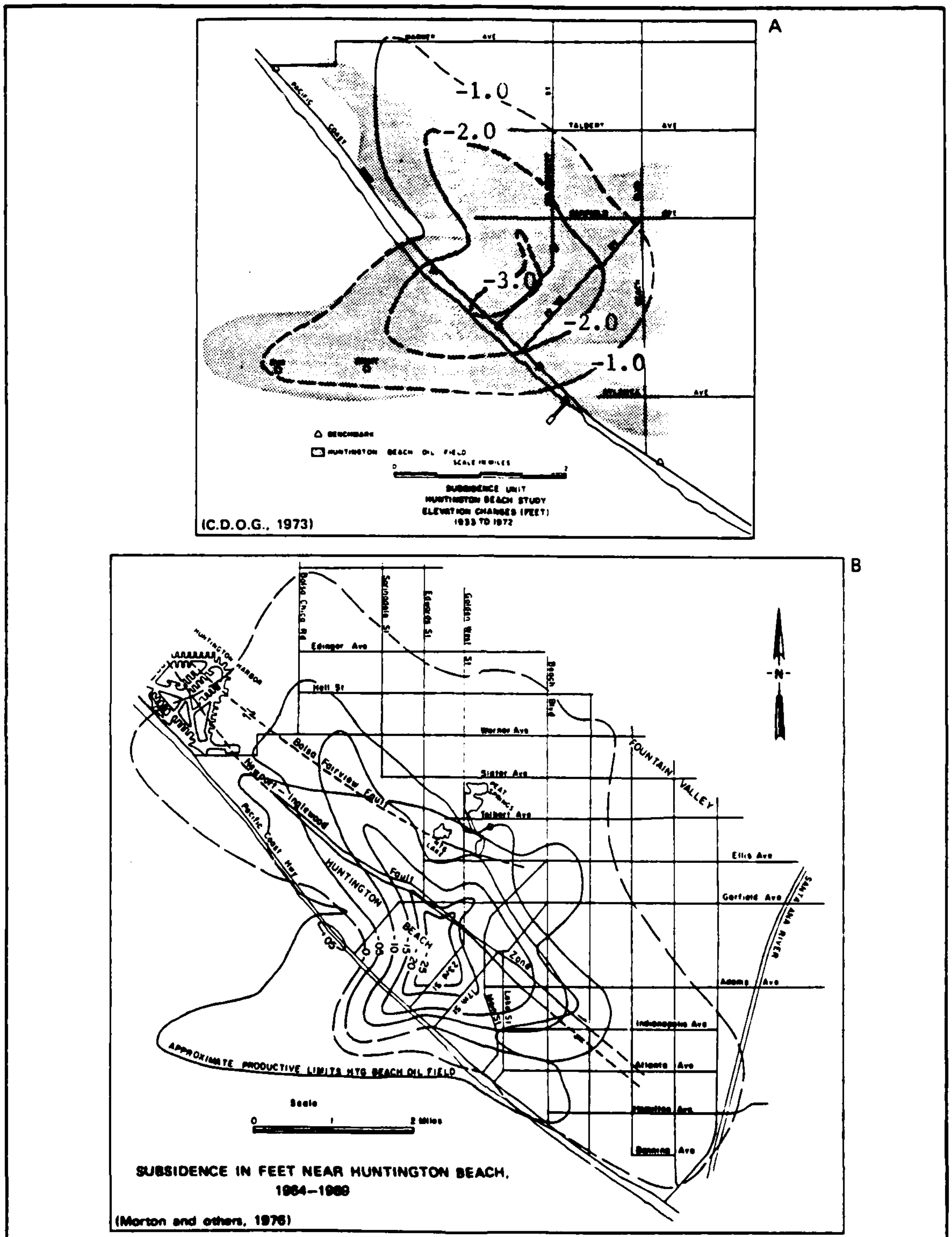
50. The major subsidence area has coincided with the limits of the Huntington Beach oil field. Historical subsidence patterns from 1933 to 1972, and from 1964 to 1969 are shown in Figure 7. The decrease in the subsidence has been attributed to water injection of oil producing zones which was initiated in 1959. Estimates of the maximum amount of subsidence have ranged up to 5 ft since 1920 when oil production began. The maximum range of subsidence from 1955 to 1968 was reported as 0.15 ft (1.8 in.) per year, but this rate decreased to 0.05 ft (0.6 in.) per year from 1968 to 1972 (California Division of Oil and Gas 1973).

51. Subsidence rates from 1976 to 1985 have been calculated by analyzing precise leveling data of benchmarks in the area obtained from the Orange County Surveyor's Office. The history of subsidence in the areas was presented for the periods from 1976 to 1982, 1976 to 1985, and 1982 to 1985. The average annual subsidence rates for these periods are presented in Figures 8 through 10, respectively. Review of these figures indicate that although subsidence is continuing across the site, it appears that in the last several years it is occurring at a lower rate. The annual subsidence over the site is estimated to continue at an average rate of 0.01 ft per year, based on the rates from 1982 to 1985. However, the subsidence in the area is considered to be primarily due to hydrocarbon withdrawal, and the rate should respond closely to oil extraction and water injection.

Sea Level Rise in the Bolsa Chica Area

52. The annual average rate of mean sea level rise along the California coast is approximately 0.005 ft per year, based on available tide gage records. A 0.5 ft per century rate is also considered the global average of sea level increase over the past century (Revelle 1983).

53. Various projections of future sea level rise have been proposed, and are illustrated in Figure 11. Work summarized by Hoffman et al. (1983) and Hoffman (1983) foresees the possibility of rates of increase with upper limits exceeding an average of 9 ft per century over the next 120 years. These projections are based on fundamentally unverifiable computer models of global warming given past and projected increases in atmospheric carbon



Project: BOLSA CHICA DEVELOPMENT Project No. 41592A	MAPS SHOWING HISTORICAL SUBSIDENCE NEAR HUNTINGTON BEACH

Figure 7. Historical subsidence near Huntington Beach, California (after Woodward-Clyde Consultants 1984)

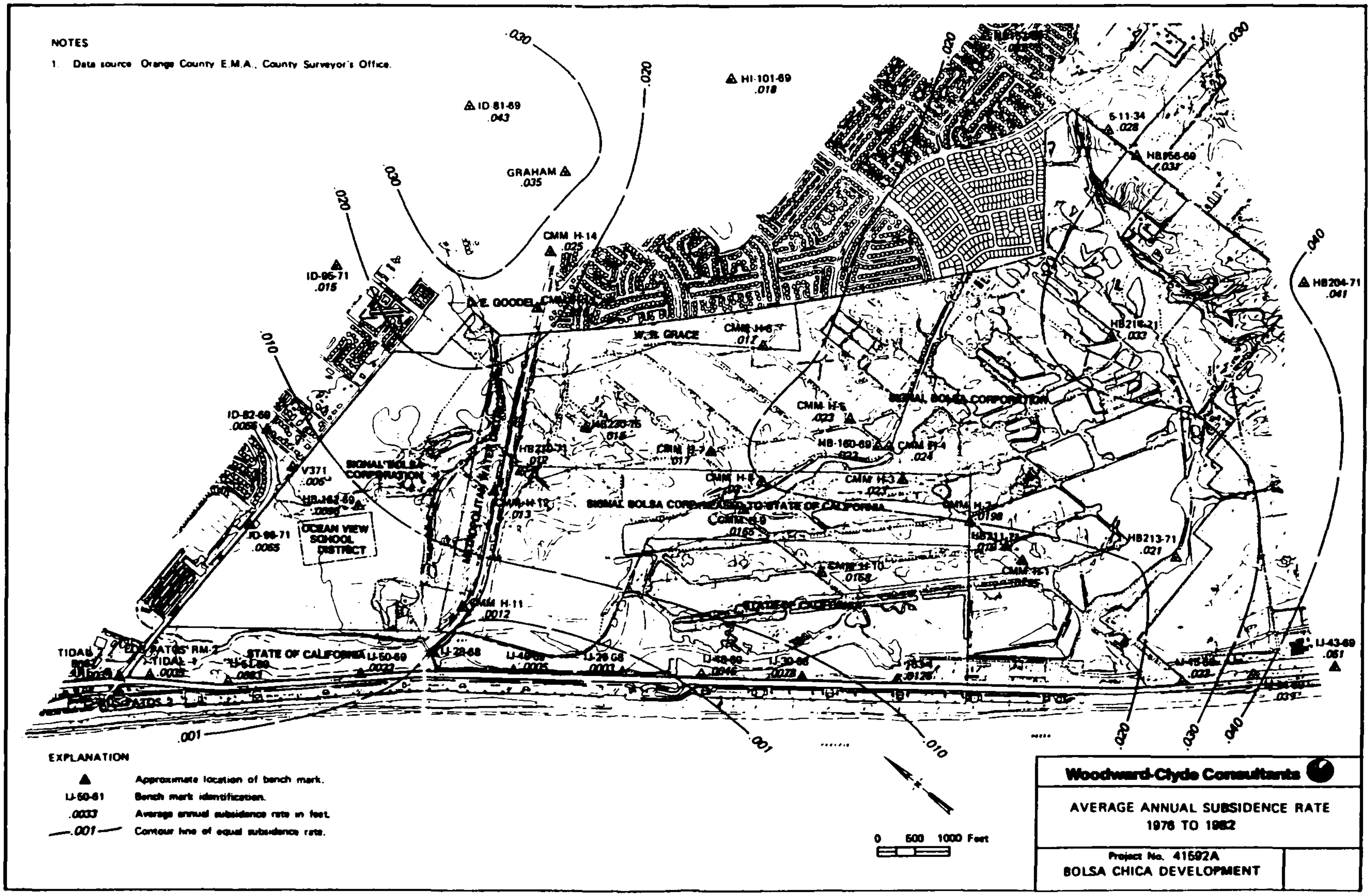


Figure 8. Average annual subsidence rate, 1976 to 1982, Bolsa Chica region (after Woodward-Clyde Consultants 1984)

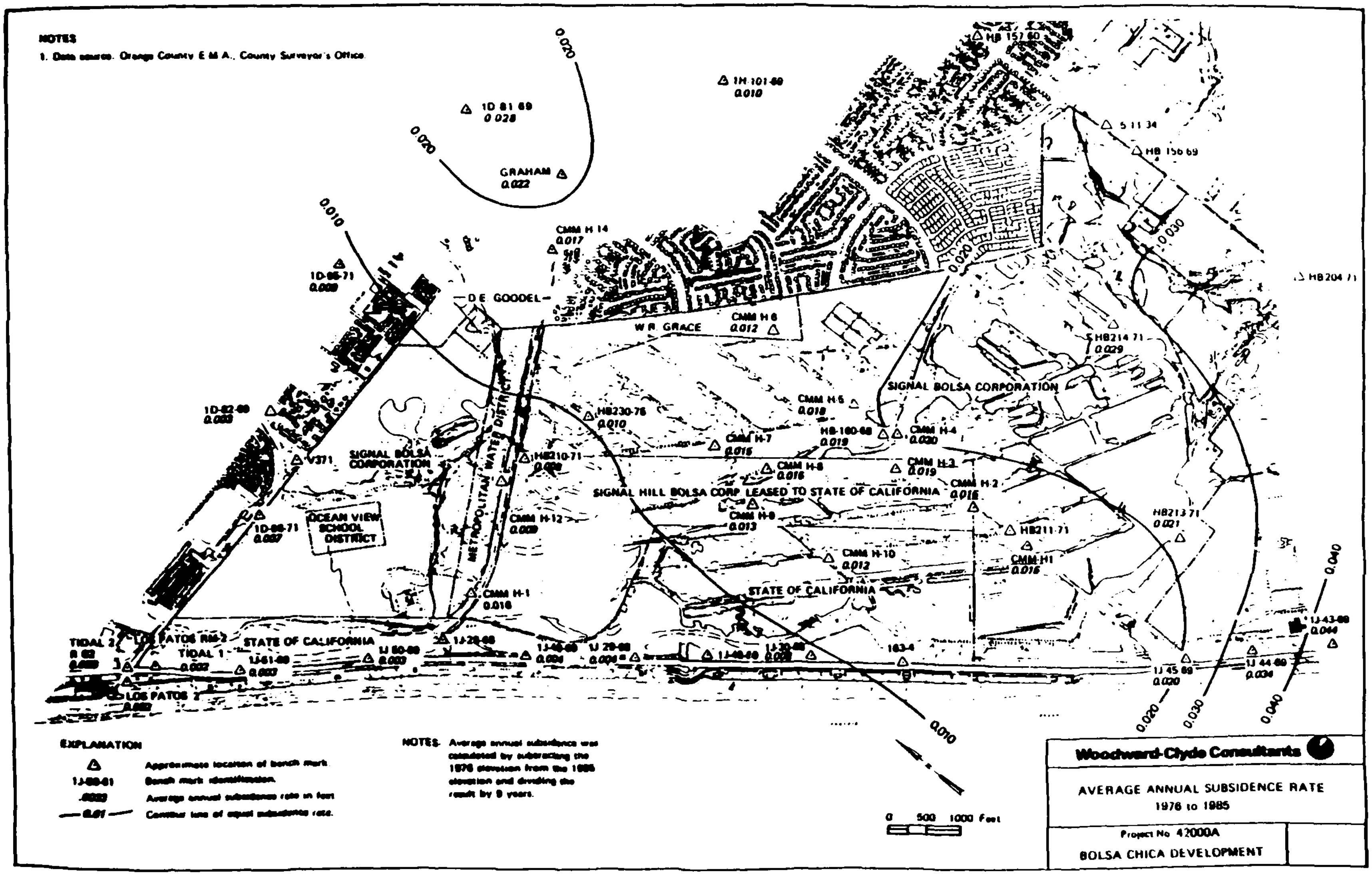


Figure 9. Average annual subsidence rate, 1976 to 1985, Bolsa Chica region (after Woodward-Clyde Consultants 1986)

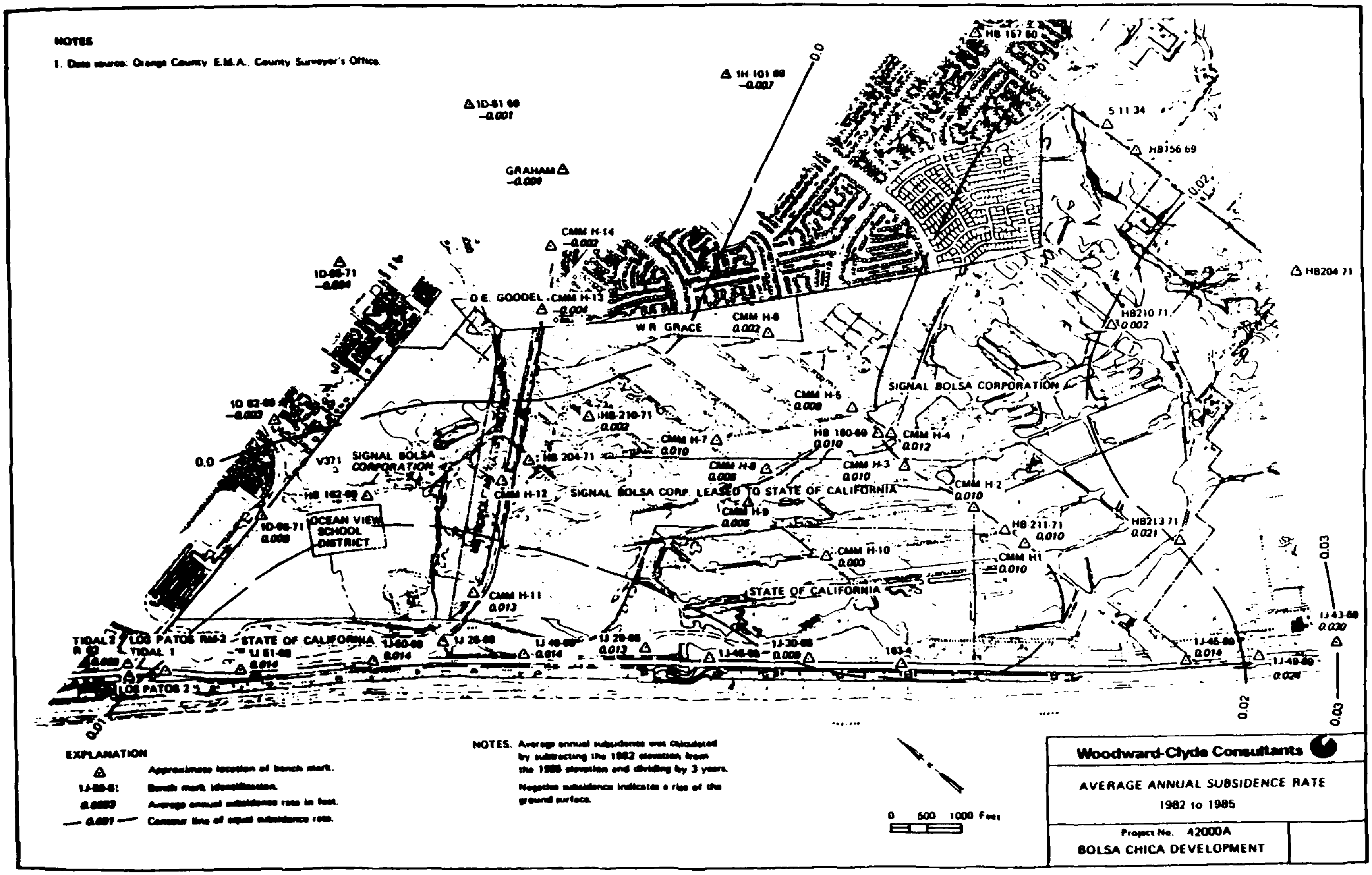


Figure 10. Average annual subsidence rate, 1982 to 1985, Bolsa Chica region (after Woodward-Clyde Consultants 1986)

dioxide and other greenhouse gases, including methane and chlorofluorocarbons. These scenarios contain a large amount of uncertainty, as reflected in the wide range of estimates shown in Figure 11 (Seidel and Keyes 1983). The most recent study by the Marine Board (1987) predicts a rate of increase of 1.3 ft per century (0.013 ft per year), and is recommended for 25-year design projects. However, the historical rate of sea level rise has been only approximately 0.5 ft per century.

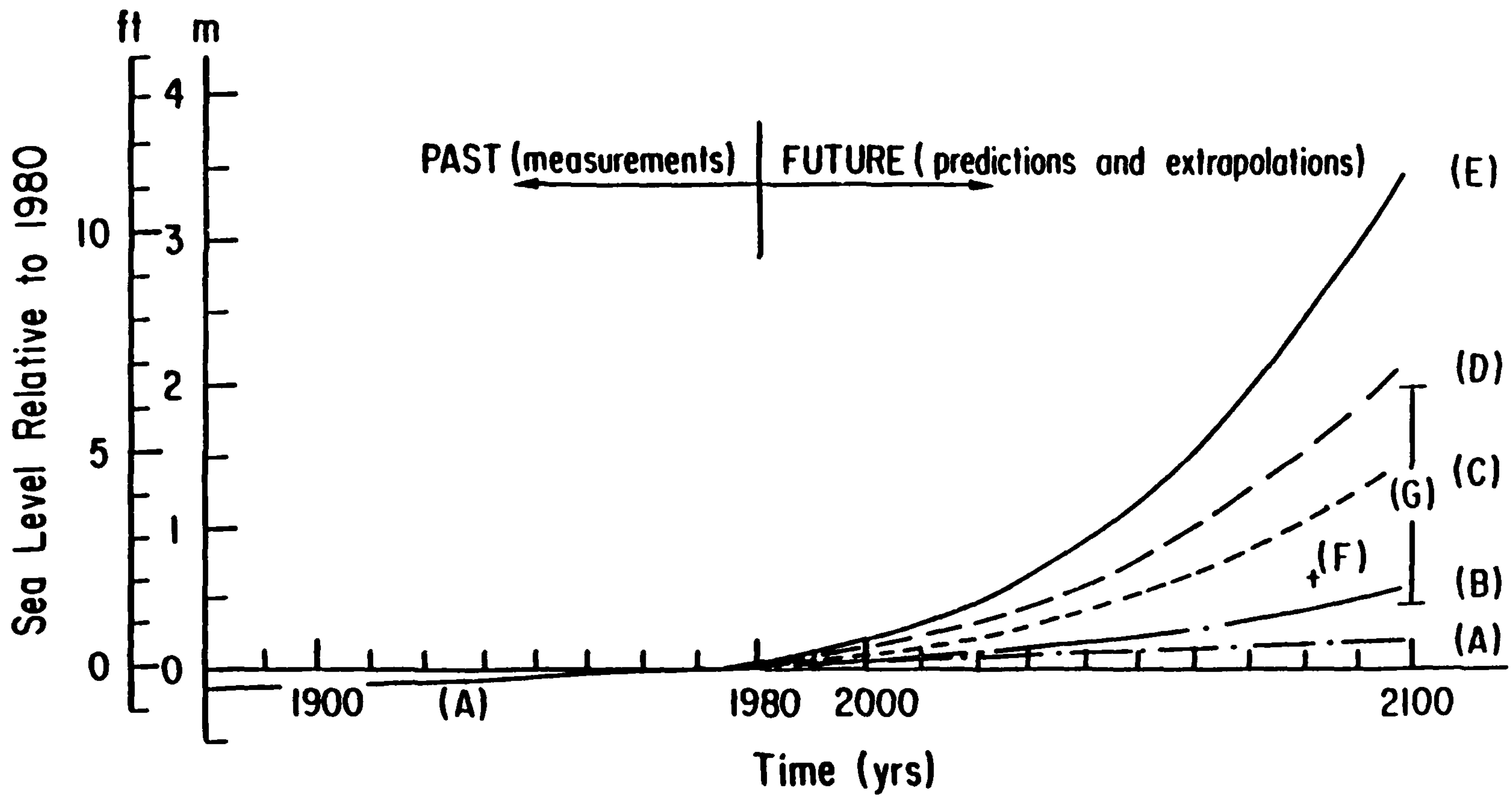


Figure 11. Schematic of eustatic sea level rise curves, (A) Rate of rise over last century projected into the future, (B), (C), (D), and (E) Hoffman et al. (1983) estimates respectively for conservative, mid-range low, mid-range high, and high rates of increase, (F) Revelle (1983), (G) Polar Research Board estimate augmented for thermal expansion (Revelle 1983) (after Dean 1986)

PART III: TIDAL CIRCULATION AND TRANSPORT NUMERICAL MODEL

54. To study impacts of proposed entrance channel, marinas, and wetland enhancement modifications at Bolsa Bay, WES required a hydrodynamic numerical simulation model for tidal flows that would include numerous channels and tidal flats in the interior wetland areas. The model was required to also be capable of simulating constituent transport in the study area. Because of its unique features and extensive application, the model selected for utilization is DYNamic TRANsport (DYNTRAN). DYNTRAN is a version of the group of link-node models called the Dynamic Estuary Model (DEM), which were developed by Water Resources Engineers (later incorporated into Camp Dresser & McKee) to study circulation and water quality in San Francisco Bay in the 1960s.

55. Major modifications since that time have included the incorporation of tidal flats to simulate the circulation in Charleston Harbor, SC. This version was then used for a flood insurance study for the US Army Corps of Engineers (USACE) in New York City, and was then further modified to include salt and non-conservative constituent transport in Little Sarasota Bay, FL. This code also has been previously applied satisfactorily to San Diego, CA, and Norfolk Harbor, VA, for the US Navy. The Navy is presently applying this model to study various hydrodynamic phenomena at (a) Pearl Harbor, HI; (b) Mayport, FL; (c) Everett Harbor, WA; (d) Bremerton Harbor, WA; (e) Alameda Naval Base, CA; (f) Portsmouth, VA; (g) Long Beach Naval Shipyard, CA; and (h) Philadelphia Naval Shipyard, PA. Because of its successful application, the model DYNTRAN has been utilized extensively.

Processes and Features Simulated by DYNTRAN

56. DYNTRAN has the capability of simulating numerous processes pertaining to estuarine and riverine circulation. Many of the processes inherent to DYNTRAN are not applicable to the Bolsa Bay study because of the geometry of the bay system. The essentially linear channel system is ideally suited for incorporating the following processes:

a. Tides,

b. Friction,

c. Spatially discrete inflows of water,

d. Mass transport of constituent with a first order decay, and

e. Inflow with tracer from specific locations.

The following features were previously included in the model:

a. x and y nodal locations,

b. Water surface area as a function of depth,

c. Friction coefficient as a function of depth,

d. Echo of input data,

e. Daily summaries of program variables,

f. Line printer plots of nodal elevations,

g. Nodal network map on line printer,

h. Statistics on tidal volume changes and boundary flows during the simulation, and

i. Dynamic mass transport solution at any integer multiple of the hydrodynamic time step.

57. Because of the unique features of the Bolsa Bay complex, it was necessary to modify DYNTRAN to include trapezoidal channels as well as rectangular channels, and to properly consider both box and circular culvert systems. The inclusion of rectangular channels of varying side slopes was straightforward. The modifications to simulate flow through culvert systems required routing the flow through the culvert section directly within the momentum equation calculations. Because a culvert length would generally violate the Courant-Frederick-Levy stability condition, the culvert was effectively elongated and Manning's n friction parameter was adjusted to compensate for the new length using equivalent pipe theory. It then became necessary to calculate the geometry of flow through the culverts as they alternate between being fully submerged at high tide, partly submerged, and/or fully exposed at low tide. The method of calculation was based on the work of Chow (1959) and Bodhaine (1968), who reported on a number of laboratory studies with various types of culverts. The energy loss across the culvert is incorporated into the model as a loss per length of culvert, and added to the Manning head loss term.

Link-Node Network

58. As discussed by Moore and Walton (1984), the prototype system is divided into a network of nodes and links (Figure 12). A node is a point in the system at which the geometric properties of volume and surface area are prescribed. A link is defined as a hydraulic channel or pathway, along which flow from one nodal volume moves to an adjacent nodal volume. Properties described in a link are (a) length, (b) cross-sectional area, and (c) flow. A link-node systems consists of a flexible arrangement that can fit any complex geometry, including islands and embayments.

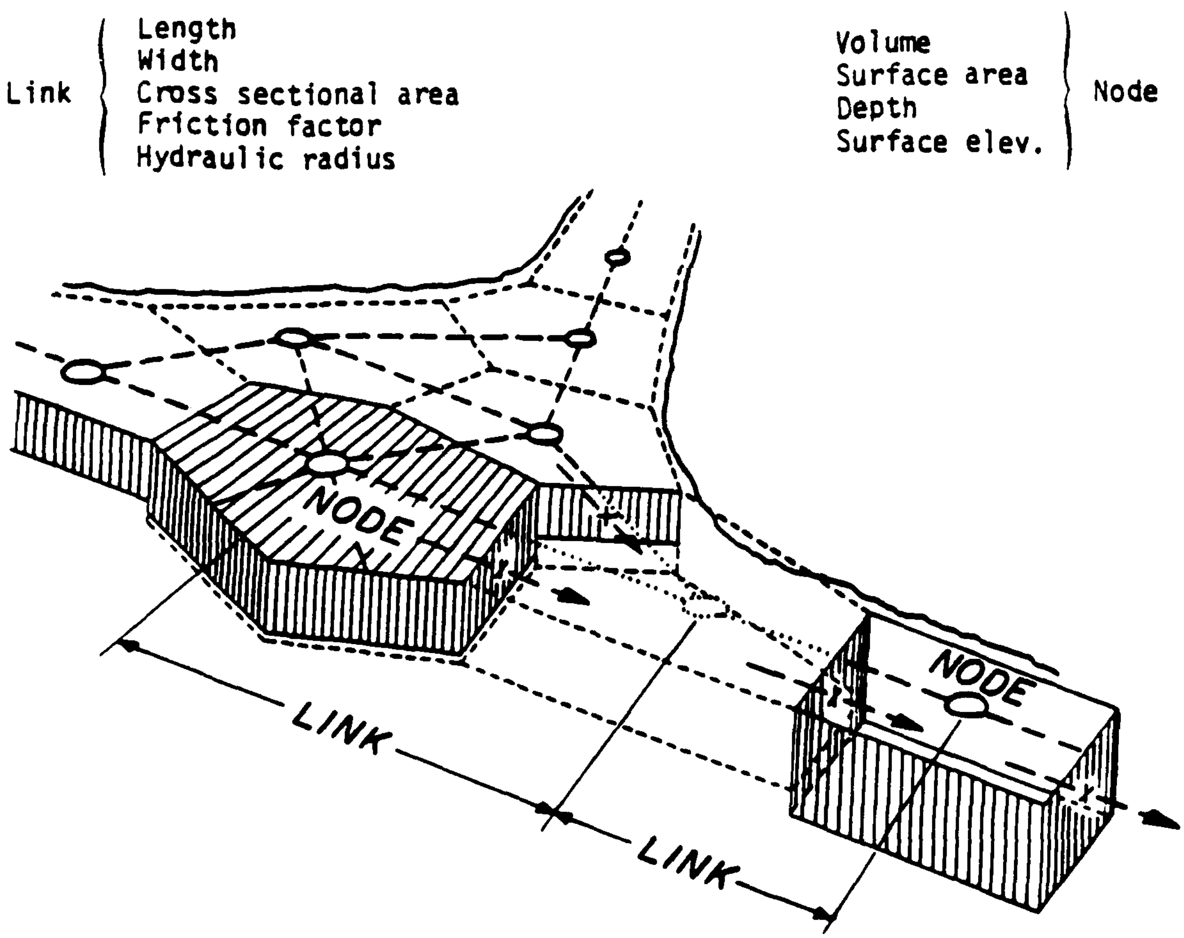


Figure 12. Geometric representation of the Link-Node system (after Moore and Walton 1984)

Governing Equations

Hydrodynamic model

59. The hydrodynamic model solves the one-dimensional equations describing the propagation of a long wave through a shallow water system while conserving both momentum and volume. The equation of motion, based on the conservation of momentum, predicts water velocities and flows. The equation of continuity, based on the conservation of volume, is used to compute surface elevations (heads) and volumes. This approach assumes that flow is predominantly one-dimensional along each link, that Coriolis and other accelerations normal to the direction of flow are negligible, that channels which correspond to each link have uniform cross-sectional area, that the wave length is significantly greater than the depth, and that bottom slopes are moderate. The momentum equation is expressed as:

$$\frac{\partial u}{\partial t} = - u \frac{\partial u}{\partial x} - g \frac{\partial H}{\partial x} - g S_f - \frac{g}{2} \frac{R}{\rho} \frac{\partial \rho}{\partial x} \tag{1}$$

and the continuity equation is:

$$A_s \frac{\partial H}{\partial t} = \sum_{k=1}^{K} (Q_k + Q_I) \tag{2}$$

where

u = velocity, ft/sec

t = time, sec

x = distance, ft

g = gravitational acceleration, ft/sec^2

H = water surface elevation above datum plane, ft

S_f = energy gradient, dimensionless

R = hydraulic radius, ft

ρ = density, lb/ft^3

A_s = surface area at a junction, ft^2

K = number of links into junction, dimensionless

Q_k = sum of flows to a junction, ft^3/sec

Q_I = inflow from boundary at a junction, ft^3/sec

The energy gradient, S_f , uses Manning's equation:

$$S_f = \frac{n^2\ u\ |u|}{2.2\ R^{4/3}} \tag{3}$$

where n = Manning's friction coefficient, sec/ft$^{1/3}$.

60. The Manning friction coefficient, n , may be specified for each node, or replaced in **DYNTRAN** by the functional form:

$$n = \frac{a}{d^{1/2}} \tag{4}$$

which was developed from a regression analysis of the variation of Manning's n with depth in a number of model applications. The probable range for the coefficient a is 0.08 to 0.12. This relationship was developed, however, for systems with deeper segments, and this relationship is not clearly applicable to a shallow wetland area.

Transport model

61. The governing equation for the mass transport model is:

$$\frac{\partial}{\partial t}(V_i\ c_i) = \sum_{k=1}^{K}(Q_k\ \bar{c}_k) + Q_I\ c_I - \sum_{k=1}^{K}(A_k\ E_L\ \frac{\partial c_k}{\partial x}) - V_i\ D_i\ c_i \tag{5}$$

where

V_i = volume of junction, ft^3

c_i = constituent concentration at junction, parts per billion

$\bar{c}_k$ = constituent concentration in channel k, parts per billion

c_I = inflow concentration, parts per billion

A_k = cross-sectional area of channel, ft^2

E_L = longitudinal dispersion coefficient, ft^2/sec

D_i = decay coefficient for constituent only, 1/sec

The dispersion coefficient, E_L , is calculated as:

$$E_L = K_L\ R\ u \tag{6}$$

where K_L is a dimensionless longitudinal dispersion coefficient.

Boundary Conditions

62. **DYNTRAN** requires both hydrodynamic and mass transport boundary conditions. For the hydrodynamic model, flow and ocean tidal boundary conditions can be specified. Rivers and inflows are treated as inflows to a given junction. The flows can be specified as a constant rate, or as a hydrograph with flow rates given at specific times. Astronomic tidal boundary conditions can be either read in directly, or developed by the program using a least squares curve fit to the observed high and low water elevations. For a semi-diurnal tide, the tidal period, T, is approximately 12.42 hr, and for a diurnal tide, the period is approximately 24.84 hr. Exact values depend on specific location.

63. For the mass transport model, lateral inflow concentrations corresponding to times and locations of water inflow are specified. At the tidal boundaries, a "flux" type condition is used in which no variation is used during the ebb tide. However, a decay relationship is used during the flood tide in which the low tide concentration decays to within five percent of the receiving water concentration after τ hr:

$$c_b = c_{RW} + (c_{LT} - c_{RW})\, e^{-3t/\tau} \tag{7}$$

where

c_b = boundary concentration, parts per billion

c_{RW} = receiving water concentration, parts per billion

c_{LT} = boundary low tide concentration, parts per billion

τ = decay time, sec

Numerical Solution

64. **DYNTRAN** is an extension of the class of models using a link-node approximation and a half-step/full-step solution technique. The hydrodynamic solution proceeds at a time interval Δt as follows:

a. Update solution variables at the beginning of a time step, t,

b. Impose tidal elevation boundary conditions at the half-step, $t + \Delta t/2$,

c. Compute velocities in all channels at the half-step, $t + \Delta t/2$, using the momentum equation (Equation 1),

d. Update flows, Q, at the time half-step, $t + \Delta t/2$,

e. Compute elevations at all junctions at the half-step, $t + \Delta t/2$, using the continuity equation (Equation 2),

f. Impose tidal elevation boundary at full-step, $t + \Delta t$,

g. Compute velocities in all channels at full-step, $t + \Delta t$, using the momentum equation (Equation 1) and values at t and $t + \Delta t/2$, and

h. Compute elevations at all junctions at the full-step, $t + \Delta t$, using the continuity equation (Equation 2) and values at t and $t + \Delta t/2$.

65. The mass transport solution proceeds at a time step Δt_{MT} which is a user-specified integer multiple of Δt. The solution scheme used is explicit in time, and is projected upwind in space based on the link velocity. It should also be noted that the inclusion of the mass transport model increases computation costs very little, and it is recommended that the user set $\Delta t_{MT} = \Delta t$ for best accuracy when running the combined hydrodynamic and mass transport models. The scheme proceeds as follows:

a. Update solution variables at the beginning of a time step, t, and,

b. For each constituent included (salt and/or non-conservative constituent) calculate values at time level $t + \Delta t_{MT}$ using flows and concentrations at time t, and volumes at time $t + \Delta t_{MT}$.

Stability Conditions

66. The hydrodynamic model must obey the usual Courant-Frederick-Levy stability condition for each channel:

$$\Delta t \leq \frac{\Delta x}{\sqrt{g\ d}} \tag{8}$$

The mass transport model also must obey the explicit advection condition in each channel:

$$\Delta t \leq \frac{\Delta x}{|u|} \tag{9}$$

and a dispersion condition:

$$\Delta t \leq \frac{(\Delta x)^2}{4\ E_L} \tag{10}$$

The stability condition for hydrodynamics, and the advection and dispersion conditions for mass transport, were all obeyed in the numerical simulations.

Numerical Dispersion

67. **DYNTRAN** solves the transport equation using a combination of Leith's method and upwind differencing (Roache 1972). Leith's method is a transport scheme which limits numerical dispersion, but introduces trailing negative waves. Upwind differencing is a highly diffusive scheme which does not produce negative oscillations. **DYNTRAN** employs Leith's method when the velocity and the concentration gradient are in the opposite direction, but switches selectively to an upwind scheme to control negative trailing oscillations when velocity and concentration gradients are in the same direction. A complete description of this approach may be found in the **DYNTRAN** user's manual (Moore and Walton 1984). The numerical dispersion introduced by Leith's method, D_{ln}, is given by Roache (1972) as:

$$D_{ln} = \frac{u^2\ \Delta t}{2} \tag{11}$$

where u is the velocity and Δt is the model time step. The numerical dispersion for upwind differencing, D_{nu}, is calculated from Roache (1972):

$$D_{nu} = \frac{u\ \Delta x}{2}\left(1 - \frac{u\ \Delta t}{\Delta x}\right) \tag{12}$$

where Δx is the length of the model segment.

Operating Modes

68. **DYNTRAN** can be run in one of two operational modes, either simultaneous or sequential simulation of hydrodynamics and mass transport. In the first case, both hydrodynamics and mass transport are simulated

simultaneously. This completely dynamic operation is useful for relatively short simulation periods (perhaps on the order of 1 to 2 weeks) in which the variability of hydrodynamic conditions might affect mass transport constituent concentrations.

69. In the second case, interest lies in very long-term simulations (perhaps on the order of months), in which transport patterns are less affected by short term hydrodynamic variability and more by long-term residual circulations. In this mode, the hydrodynamic model is run to cyclic steady-state (i.e., to a point where the elevations and velocities for two successive tidal days, 25 hr, reproduce within acceptable error limits). The hydrodynamic solution for a tidal day is then stored on magnetic tape, and used to drive the mass transport. The implicit assumption here is that the hydrodynamic conditions can be accurately simulated by repetitive tidal days for the duration of the mass transport simulation.

70. The concentrations in the mass transport calculations can be in any units. Parts per thousand is often used for salt concentrations. In selecting the units used for the second constituent, it is important to note that concentrations smaller than 0.00005 will be printed as zero. All inflows have zero salt concentrations. Therefore, tidal boundaries are the only source of salt. Constituent mass may be introduced in three ways in addition to the tidal boundary; (a) as a constant concentration and inflow rate assigned to any node, (b) as a time varying inflow hydrograph and concentration time history assigned to any node, and (c) as a time varying mass inflow rate assigned to any node.

PART IV: MODEL CALIBRATION AND VERIFICATION

71. A numerical simulation model is developed to approximate physical processes in mathematical terms to the limit of our understanding of those processes. Geometric boundaries and other characteristics of the physical system are introduced into the model, and appropriate forcing functions are applied. Some physical phenomena are not entirely understood, and their representation of the processes of interest may not be readily amenable to mathematical description. Hence, it is usually necessary that the accuracy of the simulation model be determined by a comparison of the model results with actual real world prototype field data. If the model results are not entirely satisfactory, then certain features of the system may be judiciously adjusted to induce subtle changes to the model performance. Such changes in boundary roughness, channel definition, or other topographic features to cause the model to accurately reproduce known prototype events, are known as calibration.

72. It is desirable that a numerical model be calibrated with precision prototype field data covering a specific time period, and then be verified with other completely independent prototype field data for an entirely different time period. The hydrodynamic numerical model portion of DYNTRAN was calibrated with prototype field data obtained by International Survey Services for the 11-day period of 16 August 1986 through 27 August 1986. This was a time period when the tidal range changed from extreme spring tides of approximately 8-ft range to a neap tide range of approximately 3-ft range, thus passing through the average tidal range of around 5 ft.

73. Next, the hydrodynamic model was verified with prototype field data from the 10-day period of 27 August 1986 through 5 September 1986. During this time period, the tidal range increased from approximately 3-ft neap tide to an average spring tide of around 6 ft. Here again, the tide range passed through the average tide range of about 5 ft.

74. It was determined during the calibration and verification that the constrictions created by the culvert systems dominated the hydraulic characteristics of flood and ebb flow into and out of Inner Bolsa Bay and the DFG cell. Typical values of the coefficients of roughness as represented by Manning's n value were utilized, with the culvert geometry and inundation

characteristics being utilized for hydrodynamic calibration and verification.

75. The existing version of **DYNTRAN** at the initiation of the investigation did not explicitly simulate a culvert system. In addition, although nodes were allowed to have variable surface areas with depth, channel cross sections were assumed to be rectangular (i.e., constant width in the vertical direction). This feature is appropriate, and was used, for the vertical bulkhead regions of Huntington Harbour and the proposed marina complex. Such representation is not realistic for either Anaheim Bay, the existing Bolsa wetlands, or the proposed wetland enhancement modifications. Accordingly, **DYNTRAN** was modified to permit flows through variable numbers of either box or circular culverts. In this formulation, the culvert system is considered to act as a geometric constriction with inlet and outlet losses taken as functions of velocity, and with frictional resistance depending on velocity, wetted perimeter, and equivalent culvert length. Finally, the specification of trapezoidal channel cross sections was included, where appropriate.

Existing Conditions at Bolsa Bay

76. The Bolsa Bay complex presently consists of the wetland regions of Anaheim Bay and Huntington Harbour which are connected to Outer Bolsa Bay by a bridge at Warner Avenue. Outer Bolsa Bay is then connected to Inner Bolsa Bay by a system of three 4-ft-diam circular culverts with invert elevations of -5.1 ft mean sea level (msl). The culvert system is designed so that only two culverts allow flood flow into Inner Bolsa Bay, while all three allow ebb flow from Inner Bolsa Bay. This design was intended to force the mean water elevation and tide range in Inner Bolsa Bay to conform to desired values. Inner Bolsa Bay is, in turn, connected to the DFG muted tidal cell by two box culverts each 2.5-ft-high by 4.0-ft-wide, with invert elevations of -1.0 ft msl.

77. The wetland area of Anaheim Bay, Huntington Harbour, Outer Bolsa Bay, Inner Bolsa Bay, and the DFG cell are interconnected by a complex system of channels and flow control restrictions. Tidal flow for filling and emptying the entire Bolsa Bay complex presently passes through the one connection to the Pacific Ocean at Anaheim Bay. The range of ocean tides in this area is normally about 5 ft, with spring tides averaging about 8 ft. Detailed prototype field data of tidal elevations and flow velocities were obtained for

locations in Huntington Harbour, Outer Bolsa Bay, Inner Bolsa Bay, and the DFG cell over a 3-week period from 16 August 1986 through 5 September 1986. The DFG cell was actually opened 28 August 1986 at 1400 hrs; hence, the DFG data will exist only during the WES hydrodynamic model verification phase.

78. The Huntington Harbour tidal amplitude is approximately the same as the ocean tide for both flood and ebb conditions. The Outer Bay tide rises to almost the same elevations as the Huntington Harbour tide, but falls to only about 65 percent of the low water elevation for spring tide conditions. Under those conditions, Inner Bolsa Bay tide range is muted to approximately 20 percent of Outer Bolsa Bay tide range. For lower flow rates associated with neap tides, muting through the culverts reduces the tide range in Inner Bolsa Bay to approximately 35 percent of Outer Bolsa Bay tide range. Very little muting occurs between Inner Bolsa Bay and the DFG cell due to the box culvert connection. The only muting occurs at times of lower low water when the tide elevation in the DFG cell comes near to the invert elevation of the culverts. The added friction associated with this shallow flow through the culverts mutes the ebb flow out of the cell. Higher high water elevations in the DFG muted tidal cell approximate those of Inner Bolsa Bay very closely.

Prototype Field Data for Hydrodynamic Model Calibration and Verification

79. A field data survey of the existing Bolsa Bay region was undertaken by International Survey Services, and Moffatt & Nichol, Engineers, to provide detailed measurement of tidal circulation in the Huntington Harbour and existing Bolsa Chica State wetlands. The primary purpose of this survey was to obtain accurate measurements of tidal flows into the Bolsa Chica wetlands to achieve a better understanding of the hydraulics of the area, and to provide a reliable data base for calibration and verification of numerical models. Such numerical models will be used in the further planning and design of the Bolsa Bay proposed marina complex and wetland enhancement modifications. This field data survey was sponsored by Signal Bolsa Corporation, and was reported by Moffatt & Nichol, Engineers (1986a).

80. The main objectives of the field survey were to:

- a. Provide a better understanding of the hydraulics of the study area. This included investigation of tidal muting and the associated phase lags between the Pacific Ocean, Huntington Harbour, Outer Bolsa Bay, and Inner Bolsa Bay,
- b. Measure the tidal elevations and muting of the new tidal cell (DFG cell) opened during the final weeks of the survey study,
- c. Facilitate in the further planning and design associated with the Bolsa Chica Project,
- d. Provide a reliable data base for calibration and verification of numerical models. This included calibration of channel friction coefficients and head loss factors through tide gates and culverts, and
- e. Investigate the possible existence of seiching or other oscillatory phenomena.

The scope of the field survey study consisted of the following three phases:

- a. Measurement of tidal elevations,
- b. Measurement of tidal flow velocities, and
- c. Frequency analysis of tidal elevation and current data.

Figure 13 shows the location of the tide gages and velocity current meters.

Tidal data

81. It was decided that four tide gages could adequately measure the tidal elevations in the areas of interest. To provide a broad base of data measurements, the tide elevation survey was performed over a 3-week period, with 128 data samples per gage taken ever hour. This short sampling interval was specified to obtain useful data for the frequency analysis of potential short term oscillations. This 3-week period allowed for a variety of tide ranges and tide curves. The period from 16 August through about 20 August consisted of mixed spring tides with a maximum tidal range of about 8.1 ft. The following week exhibited rather low diurnal tides on August 27-28, with a minimum range of about 3.5 ft. The end of the survey period exhibited moderate semi-diurnal tides.

82. In addition to selecting a survey period with a wide range of tides, a unique opportunity associated with this particular period was the opening of a culvert connecting Inner Bolsa Bay with a new tidal cell (DFG muted tidal cell). The opening of this tidal cell was coordinated by the DFG. Of interest was the amount of tidal flow into this new cell, and the time dependent response of Inner Bolsa Bay and the new cell immediately following

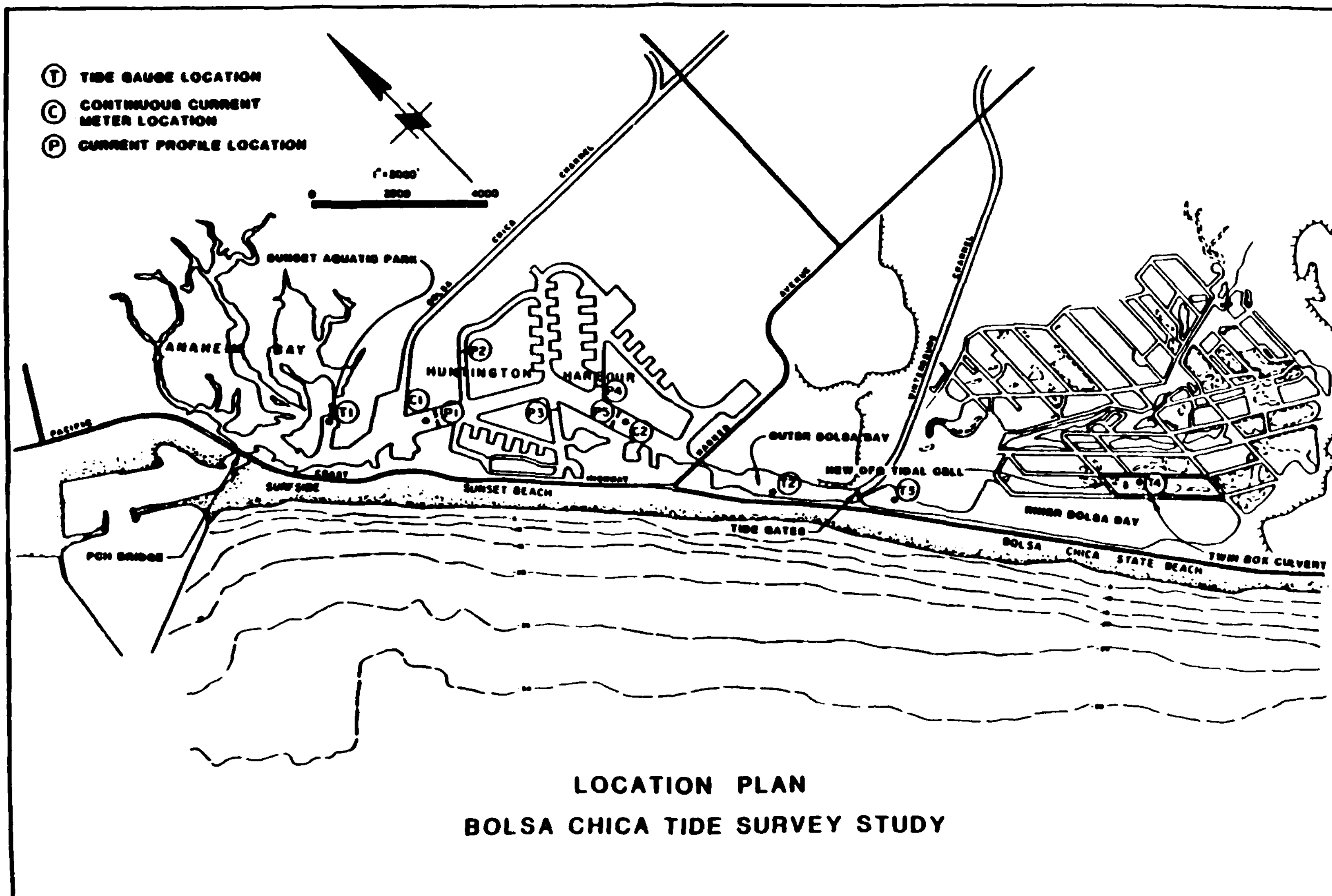


Figure 13. Location of prototype field survey tide gages and velocity meters (after Moffatt & Nichol, Engineers 1986)

opening of the culvert. The tide gage in this new cell was installed on 29 August, one day following the cell opening.

83. Four tide gages were deployed to measure tidal elevations throughout the Huntington Harbour and existing Bolsa Chica State wetland area. The following describes the measurement locations:

Tide Gage	Location	WES Node
T1	Sunset Aquatic Park	5
T2	Outer Bolsa Bay	32
T3	Inner Bolsa Bay	35
T4	New DFG Cell	54

Tide Gage T1 (WES Node 5) was installed adjacent to the harbor master dock facilities at Sunset Aquatic Park. This area was chosen due to its near proximity to the ocean. Preliminary numerical studies indicated that tide elevations in Sunset Aquatic Park and the ocean were very closely correlated due to the wide connecting channels. Tide Gage T2 (WES Node 32) was installed in Outer Bolsa Bay, bordered on the west by the Warner Avenue Bridge and on the east by the tide gates which connect to Inner Bolsa Bay. This location, which is immediately seaward of the tide gates, provides data for calibration of the head loss and associated muting through the tide gates into Inner Bolsa Bay. Tide Gage T3 (WES Node 35) was installed in Inner Bolsa Bay. These measurements can be used in conjunction with the Outer Bolsa Bay data for estimates of the tide gate head loss. Tide Gages T1 through T3 were installed for a 3-week period from 16 August 1986 through 5 September 1986. At the end of the second week, specifically 28 August 1986, the new DFG muted tidal cell was opened. Tide Gage T4 (WES Node 54) was installed in this muted tidal cell the following day for the final week of the field survey period.

Velocity data

84. The measurement of tidal flow velocities in the study area consisted of both continuous velocity measurements and "instantaneous" profile measurements. The continuous measurements were taken at two locations for periods of 22 and 39 hr. Velocity Gage C1 was located at WES Link 7, in the western portion of the main Huntington Harbour channel. Velocity Gage C2 was located at WES Link 26, in the eastern portion of the main Huntington Harbour channel. The dates for the measurement period were from 19 August 1986 through 21 August 1986. The instantaneous profile measurements were taken over a

4-hr period (from 2200 19 August 1986 through 0200 20 August 1986) within the continuous current measurement period, during relatively strong ebb flows.

Velocity Gage	Location	WES Node
C1	Western Huntington Harbour Channel	7
C2	Eastern Huntington Harbour Channel	26

85. Whereas the continuous reading current meters were in fixed "weathervaning" positions, the instantaneous profiling current meter readings were taken over five channel locations, and at various depths and locations over the channel cross sections. These measurements were taken to provide information regarding flow distributions in the channels. Such information is useful for determining mean flow velocities which ultimately may be used for calibration and verification of numerical models.

Pacific Coast Highway bridge velocities

86. Moffatt & Nichol, Engineers (1986a) also obtained velocity measurements under the Pacific Coast Highway (PCH) bridge which crosses Anaheim Bay. Three measurements were taken at the bridge centerline. As these measurements were taken at this constriction during maximum ebb flow, the velocities were quite high, the maximum measured being 3.41 ft per sec. Concern exists regarding the effects of strong currents on navigation craft which occasionally have difficulty entering and exiting Anaheim Bay under such conditions. Helical and spiral flow made by the velocity field around the relatively sharp curves approaching the PCH bridge where craft are required to maneuver tend to displace the vessels against the sides of the channel and away from safer passage ways near the center of the channel. Potential increases in velocities under the PCH bridge due to any increase in tidal prism flow under the bridge for nourishing wetland areas are of significant interest to navigation.

Hydrographic survey data

87. Hydrographic survey information for this investigation was provided to WES by SLC. These data were developed and obtained from several different sources. Anaheim Bay topography and hydrography at a scale of 1 in = 100 ft, were determined by Dunlin and Boynton, Licensed Surveyors, Signal Hill, California, in 1986. Hydrographic data for Huntington Harbour were obtained from the National Ocean Service nautical chart of San Pedro Bay and vicinity, 28th edition, 1986, at a scale of 1 in = 1,000 ft. Because of the uniform

channelized conveyance system through the harbor, and since the sides are essentially vertical bulkheads, this scale was adequate for ascertaining both link and node characteristics.

88. Initial Outer Bolsa Bay survey information were obtained from Feldmeth et al. (1980), at a scale of 1 in = 300 ft. However, it appeared the channel bottom elevations were not well defined by this survey, and it was requested that SLC arrange for a present condition survey of Outer Bolsa Bay. This new survey was conducted at a scale of 1 in = 40 ft by Williamson and Schmid, Consulting Civil Engineers and Land Surveyors, Irvine, California, in late December 1988. Indeed, the existing channel through Outer Bolsa Bay is at least a foot deeper than the earlier survey indicated (bottom elevation -4.5 ft msl or lower throughout the bay), and these depths are sufficient for maintaining flow through the Outer Bay under all proposed enhancement plan alternatives studied. It is believed that the earlier survey was less precise in this vicinity than the recent survey, and that the lower elevations in Outer Bolsa Bay were not caused by scouring. The hydrographic and topographic survey of Inner Bolsa Bay, the DFG muted tidal cell, and all other regions of interest in the study area, were also performed by Williamson and Schmid in 1986, at a scale of 1 in = 200 ft.

Hydrodynamic Model Calibration

89. Numerical simulation models can be used to analyze the characteristics of coastal projects and, through calibration, can reproduce measured conditions in the field with good accuracy. Such models also can be used to predict the behavior and characteristics of proposed projects, although such results can not be compared with a measurement to assess accuracy. However, a sensitivity analysis can be conducted to estimate the range in which the results are most likely to fall. A sensitivity analysis was conducted by Moffatt and Nichol, Engineers (1987) as part of their hydrodynamic modeling process of the existing conditions at Bolsa Bay. One purpose of the analysis was to ascertain the number of nodes necessary for applying a link-node numerical simulation model to a wetland region.

90. The topography of Inner Bolsa Bay includes islands, mudflats, tidal channels, and areas always submerged by water. At high tide the water covers

the mudflats and Inner Bolsa Bay appears as a lagoon, while at low tide mudflats are exposed and a system of channels becomes apparent. In the sensitivity analysis, three different representations of Inner Bolsa Bay were used to determine the effects of the number of nodes on the results.

91. The cases considered by Moffatt & Nichol, Engineers (1987) were (a) a one-node representation of Inner Bolsa Bay, (b) a three-node representation, and (c) a ten-node representation. A one-node representation considers Inner Bolsa Bay as a lake, where the water level rises and falls evenly throughout the wetland. The three-node and ten-node representations allow the water surface in the wetland to be defined at different locations, and variations in water elevation at various locations within Inner Bolsa Bay can be determined. As the number of nodes is increased, so is the resolution of the water surface within the wetland. The ten-node representation, therefore, allows the water surface to be defined at seven more locations than the three-node representation.

92. It was found that the tide response for each of the node representations is fairly equal except at higher high water. Here, the three-node representation is about 4.8 percent higher than the one-node representation, while the ten-node representation is about 7 percent higher. From inspection of tide measurements in Inner Bolsa Bay and the DFG cell, a marked phase lag between the two tide readings was not apparent. This indicated that the tide in Inner Bolsa Bay was fairly uniform throughout, and that the channels did not restrict the flow significantly. In the model of Moffatt & Nichol, Engineers (1987), therefore, Inner Bolsa Bay could be represented by several nodes with wide interconnecting channels, or with one node. A one-node representation was selected since the computational time could be reduced without reducing the accuracy of the results.

93. Because the WES analysis was being performed with WES-owned computer facilities, it was decided that a large number of nodes would be appropriate for providing better definition of the hydrography within the wetlands. A variable nodal surface area with elevation is provided in the numerical model, and the connecting channels have been defined to allow trapezoidal configurations. Hence, the greater the number of nodes and links in the system, the better will be the estimation of tidal prism and volume during ebb and flood. Simulation of transport characteristics also requires a

higher resolution model. One purpose of this modeling effort is the simulation of tracer transport to aid in water quality impact assessment. Nineteen nodes were judiciously positioned in Inner Bolsa Bay, 5 nodes were located in Outer Bolsa Bay, 27 nodes were placed in Huntington Harbour, 22 nodes were selected for Anaheim Bay, and 1 node was located at the entrance to Anaheim Bay to serve as the ocean boundary condition. The location of the nodes for the link-node system is shown in Figure 14 for the pre-DFG condition, which is taken to be the calibration time period. The links connecting these nodes are presented in Figure 15.

94. During the time period chosen for model calibration, tidal data stations were in operation at Sunset Aquatic Park (WES Node 5), Outer Bolsa Bay (WES Node 32), and Inner Bolsa Bay (WES Node 35). It is essential that calibration (and verification) be performed by a comparison of measured data at a location with a simulation at the same location, when the simulation was obtained from a measured forcing function for the same time period.

95. Since no tide gage was actually located in the open ocean at the entrance to Anaheim Bay, the Sunset Aquatic Park (Node 35) gage located just inside Huntington Harbour was believed adequate to utilize as the driving signal for the numerical model. To determine the appropriateness of this gage, the measured signal from the Sunset Aquatic Park gage was applied at Node 74 at the ocean entrance. The model was operated with the signal previously recorded by the Sunset Aquatic Park gage, and the simulation was obtained at the Sunset Aquatic Park location (Node 5). There appeared to be no phase lag across the entrance, and no tidal amplitude variation. This essentially total response of Node 5 to an applied signal at Node 74 can be attributed to the wide opening of the Anaheim Bay entrance, and unrestricted channels connecting the ocean with Huntington Harbour and Anaheim Bay. This comparison is shown in Figure 16. Thus, it was confirmed that the recorded signal at the Sunset Aquatic Park (Node 5) can be repositioned to Node 74 and serve as the input signal to operate the hydrodynamic numerical simulation model of Bolsa Bay.

96. The task now became one of adjusting boundary conditions so that the measured signal in Outer Bolsa Bay (Node 32) and Inner Bolsa Bay (Node 35) could be reproduced to the greatest extent possible. It quickly became apparent that the tide gates dominated flow into Inner Bolsa Bay, completely

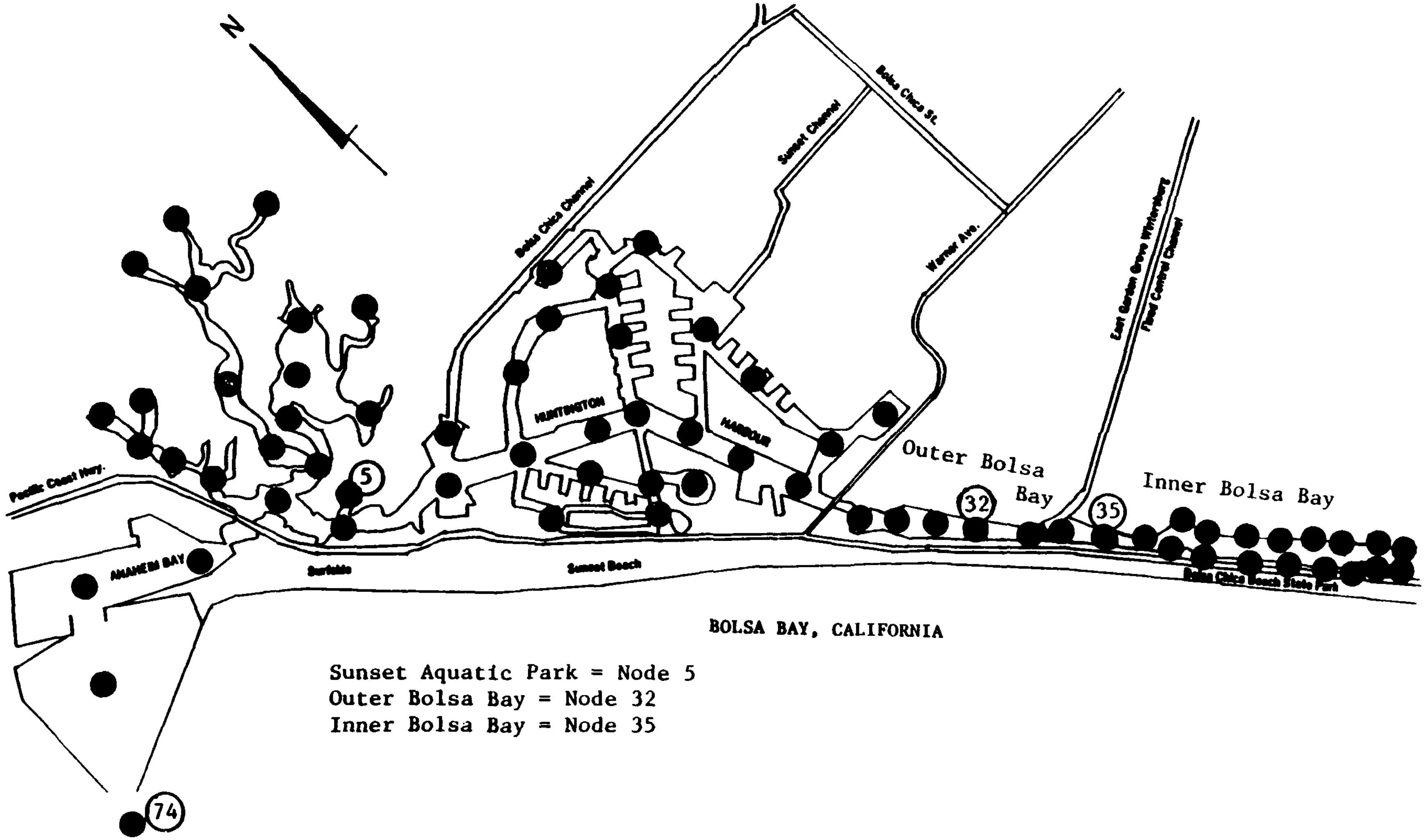
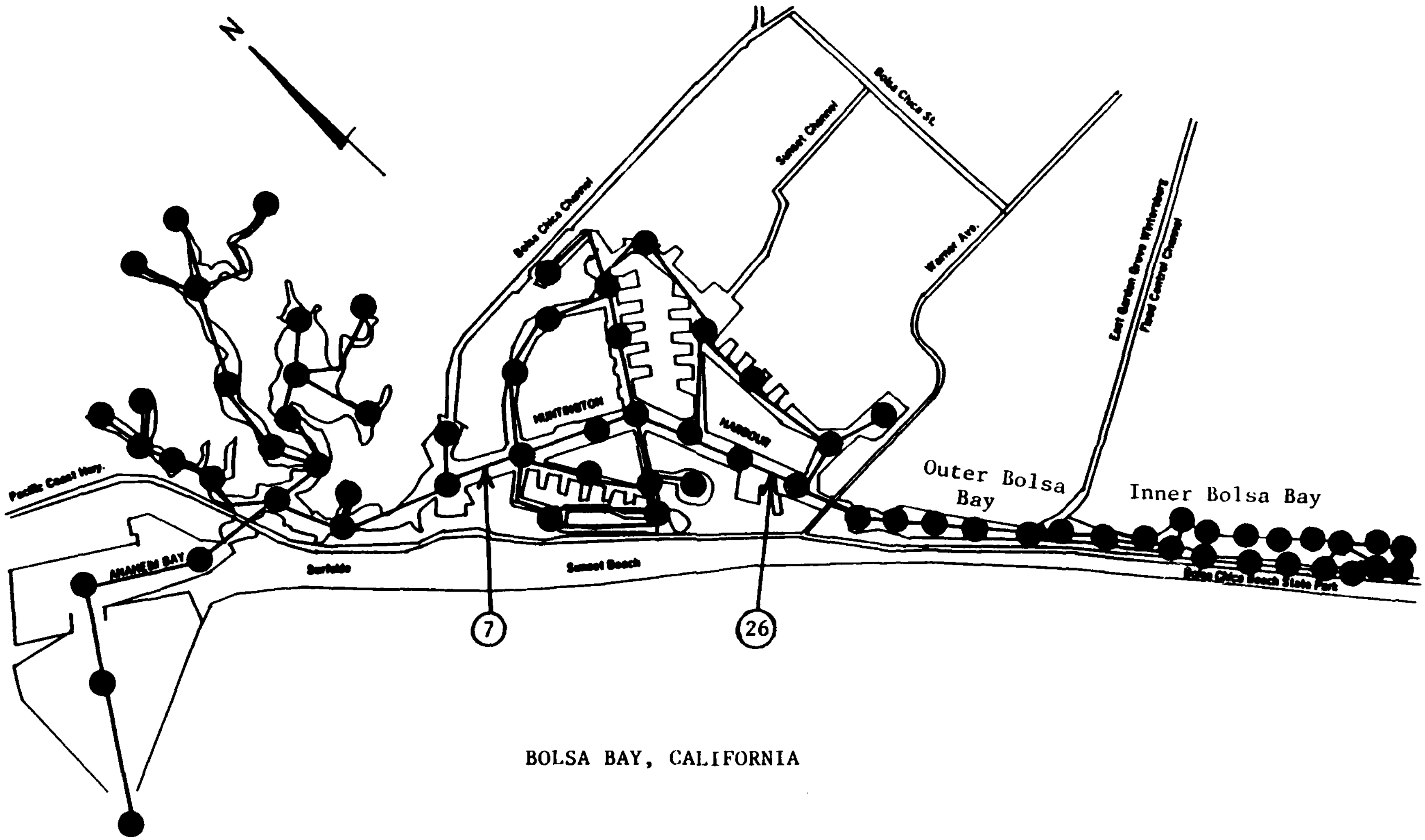


Figure 14. Location of nodes for link-node hydrodynamic model DYNTRAN, Nodes 5, 32, and 35 used for model calibration



BOLSA BAY, CALIFORNIA

Figure 15. Location of links for link-node hydrodynamic model DYNTRAN. Links 7 and 26 used for model calibration

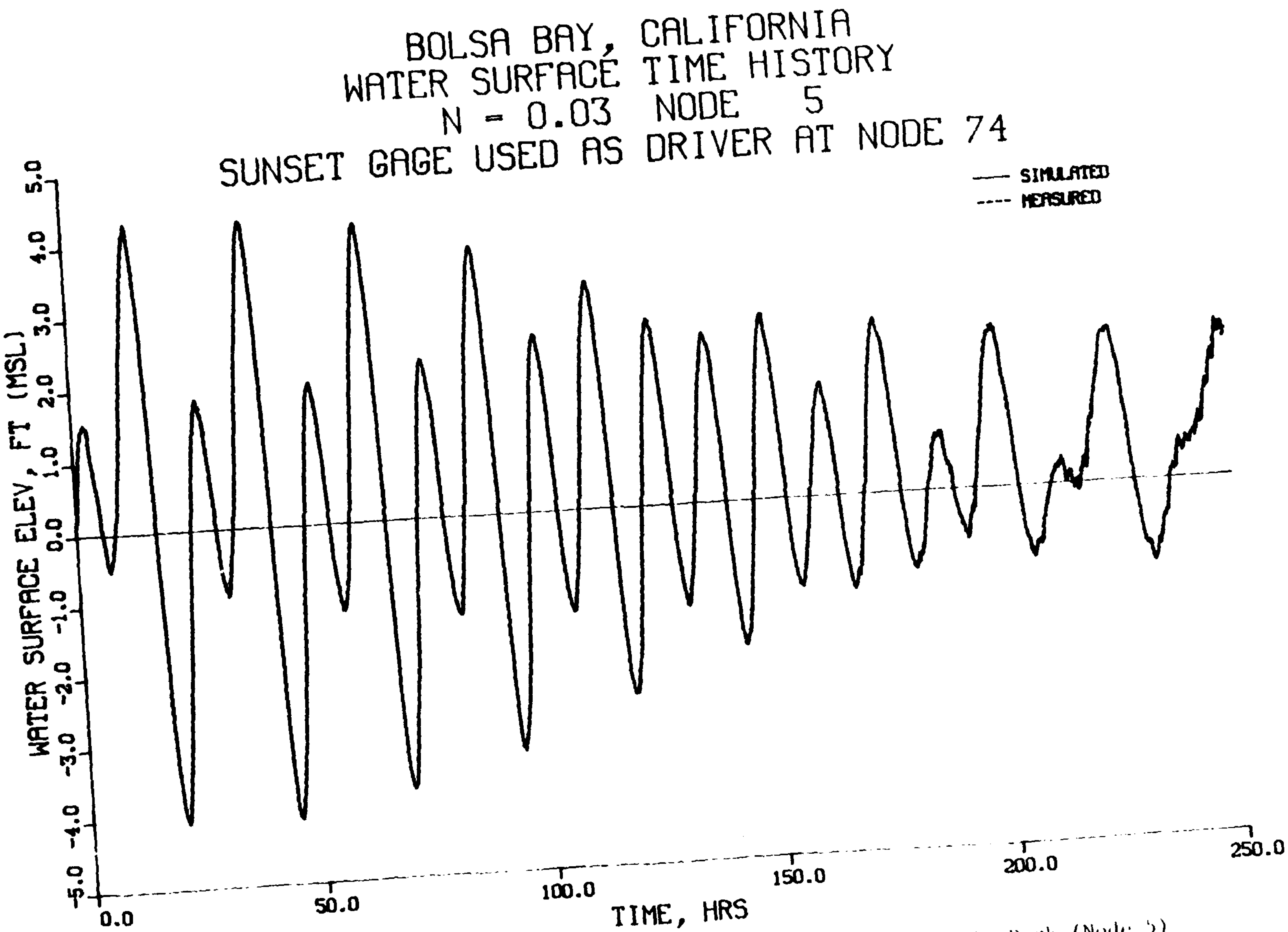


Figure 16. Simulation at Node 5 by recorded data from Sunset Aquatic Park (Node 5) being used as signal at ocean entrance (Node 74), showing essentially total response

overwhelming frictional resistance of the channels. The best available hydrographic survey data were utilized; however, some discretion exists for selecting channel widths and side slopes. These data were judiciously chosen with various values of Manning's n coefficient, the model was operated for the appropriate time period, and the results of the simulation at Nodes 32 and 35 were compared with the gaged measurements from these same locations. (It had previously been confirmed that Node 5 would reproduce precisely.)

97. When certain channel boundary data were input to the model, it was determined that a friction coefficient of $n = 0.03$ for the system was satisfactory since the tide gates dominated the Inner Bolsa Bay tidal characteristics. It was concluded that the simulations for Nodes 32 and 35 (Figures 17 and 18) were the best reproduction of the measured tidal signals at these locations. The hydrodynamic model begins simulation with all nodal elevations at mean sea level (msl). However, the observed water surface elevation at Node 35 was approximately 1 ft below msl at the time model simulation began. Hence, it was necessary for the numerical model to operate for around 2 days before an acceptable simulation was achieved.

Hydrodynamic Model Verification

98. The verification time period was taken to be that time immediately following the opening of the DFG new cell in the wetlands. Figure 19 shows the link-node hydrodynamic model configuration with three additional nodes for describing the DFG cell muted tidal characteristics. Because a tide gage had been positioned in the new DFG muted tidal cell (Node 54), there now existed another measured station for simulation comparison. These data are displayed in Figures 20 through 22 for Nodes 32, 35, and 54, respectively.

99. Prototype velocity measurements are obtained with a current meter positioned at a specific location in the channel cross section. It is well known that there exists contours of velocity at a cross section; i.e., for steady flow conditions in an open channel, the velocity magnitudes varies at different locations within that channel. The hydrodynamic model computes an average velocity which is considered to be constant over the entire cross-sectional area of the channel. Hence, the numerical model value of velocity may or may not be identical to that recorded by the current meter in the

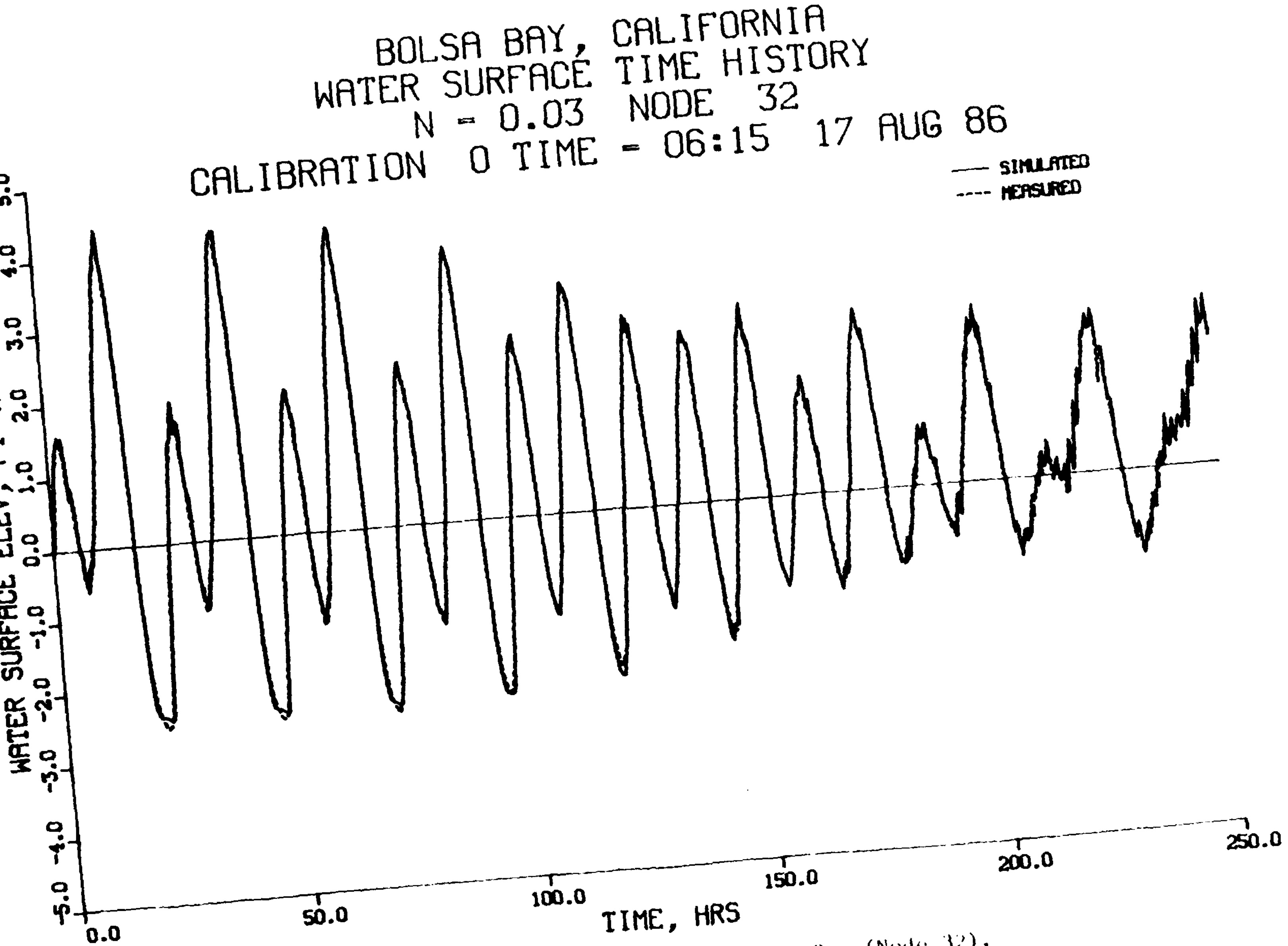


Figure 17. Calibration of Outer Bolsa Bay (Node 32), comparison of measured data versus simulation

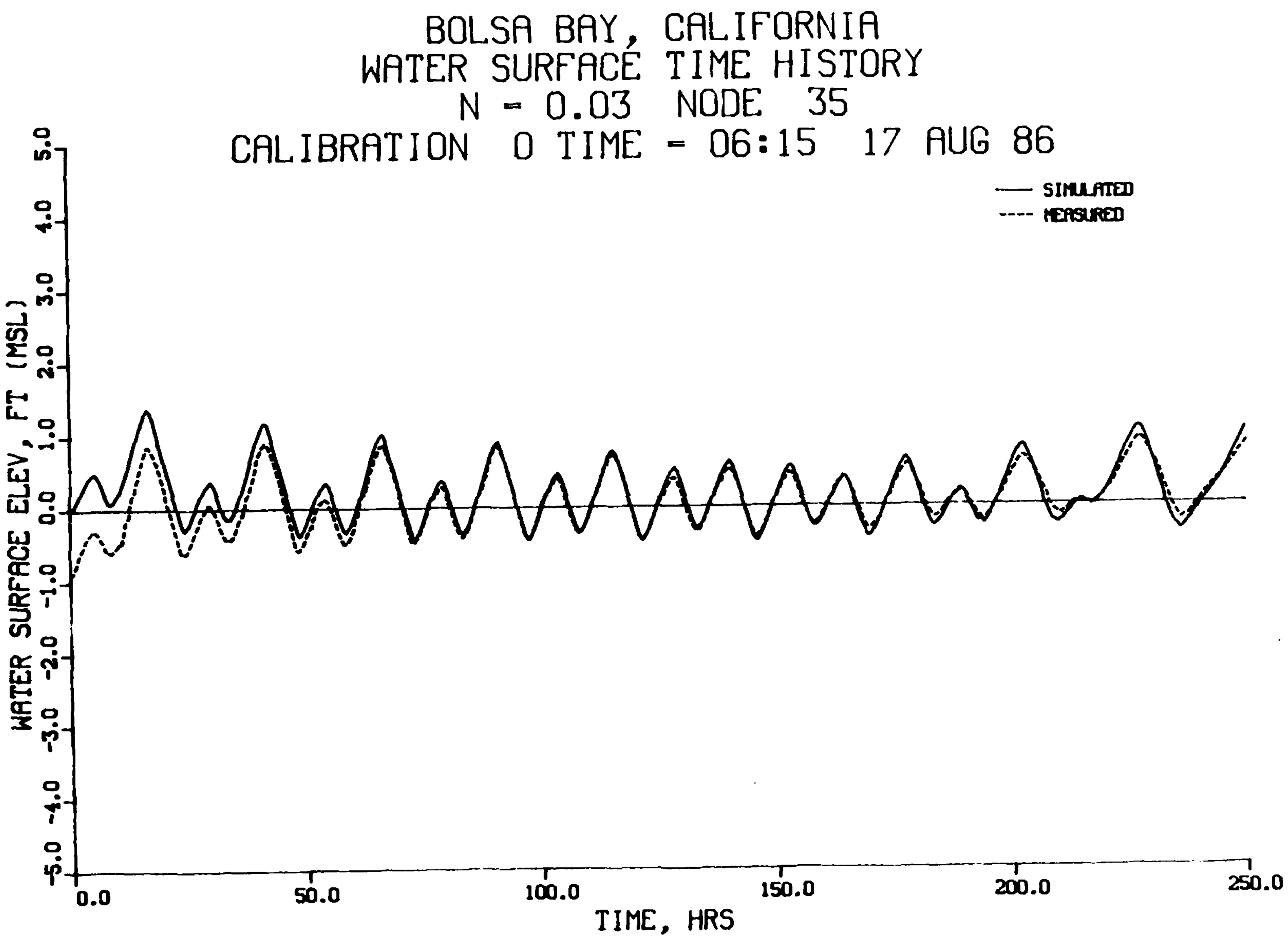


Figure 18. Calibration of Inner Bolsa Bay (Node 35), comparison of measured data versus simulation

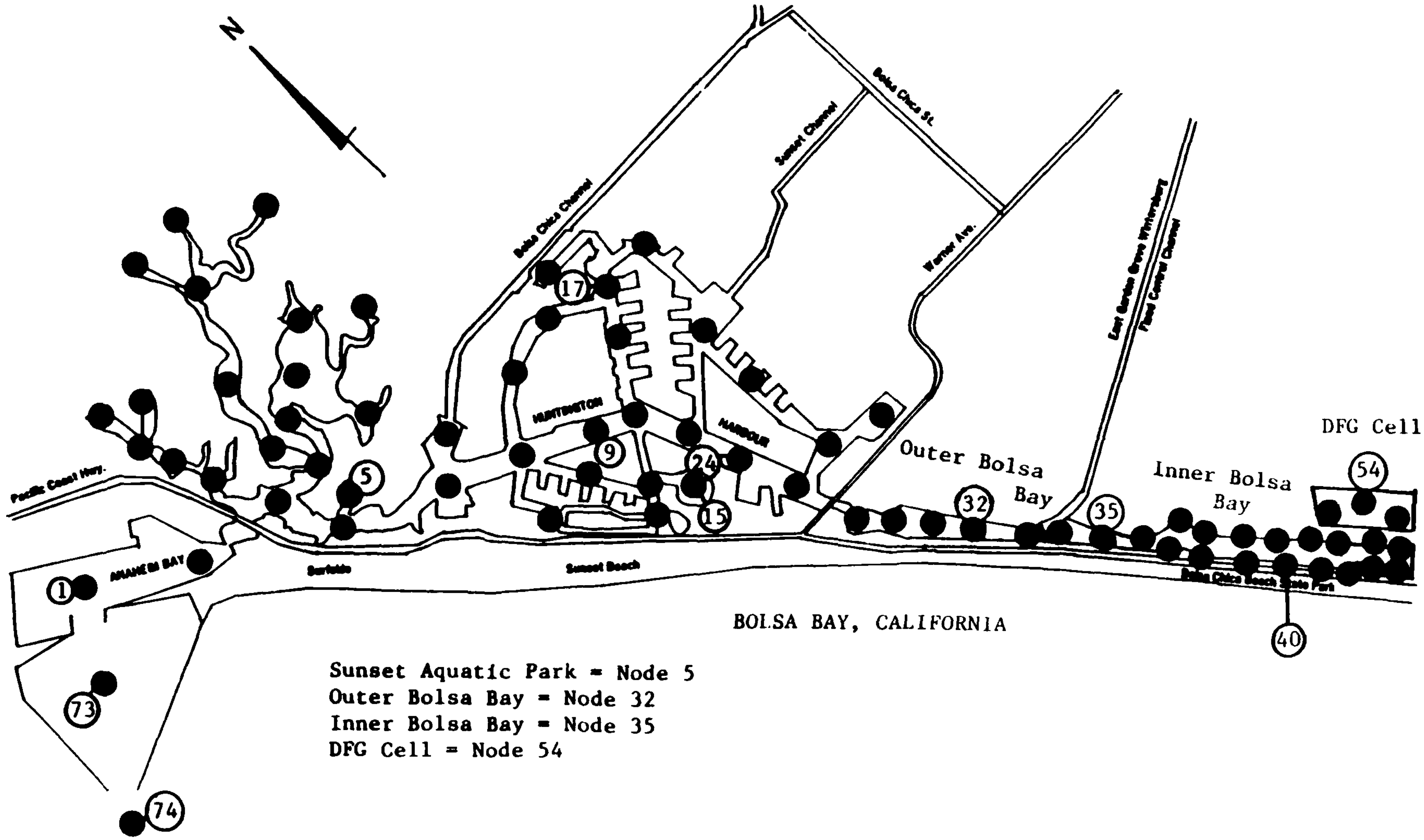


Figure 19. Location of nodes for link-node hydrodynamic model DYNTRAN, Nodes 5, 32, 35, and 54 used for model verification

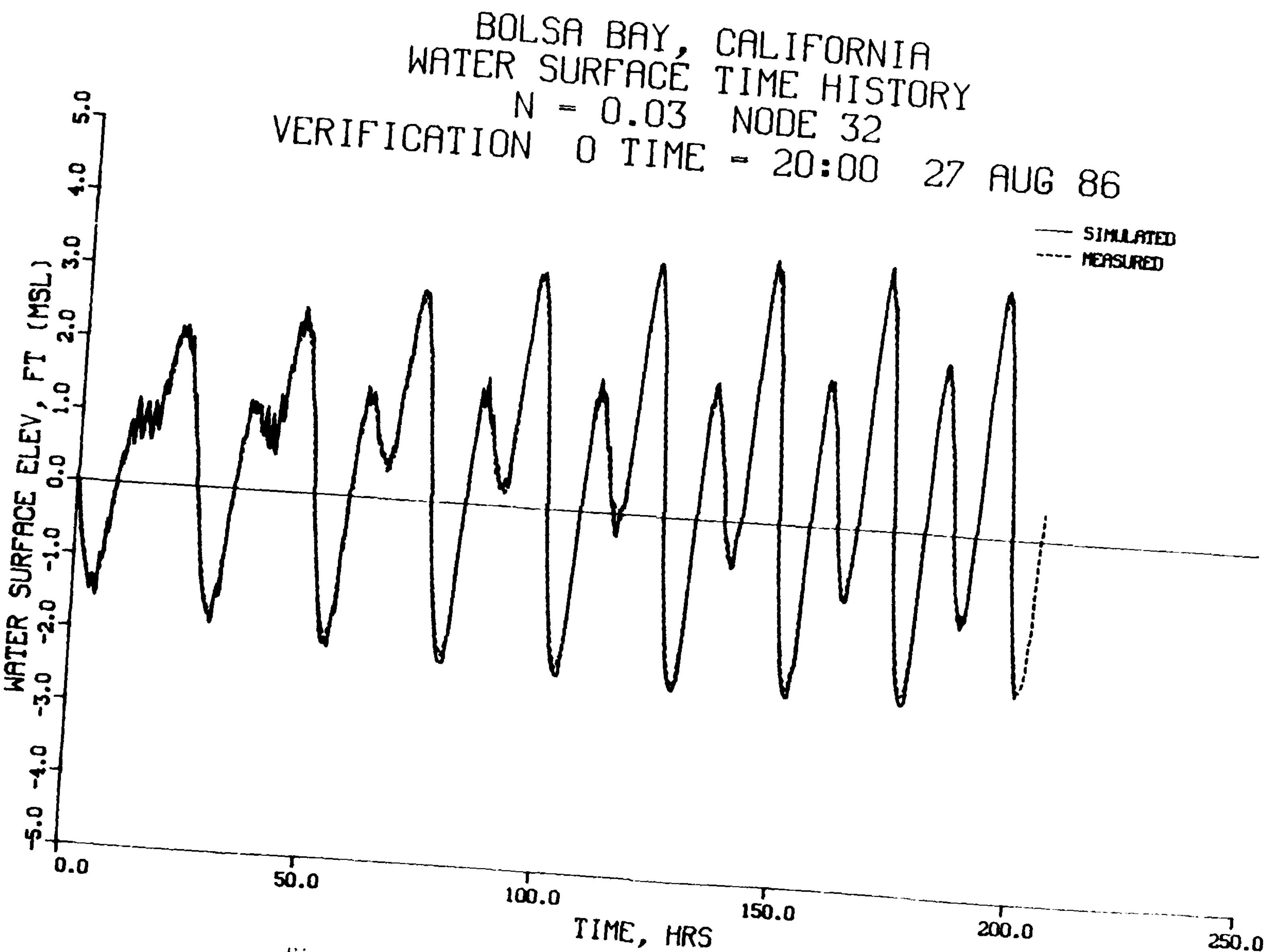


Figure 20. Verification of Outer Bolsa Bay (Node 32), comparison of measured data versus simulation

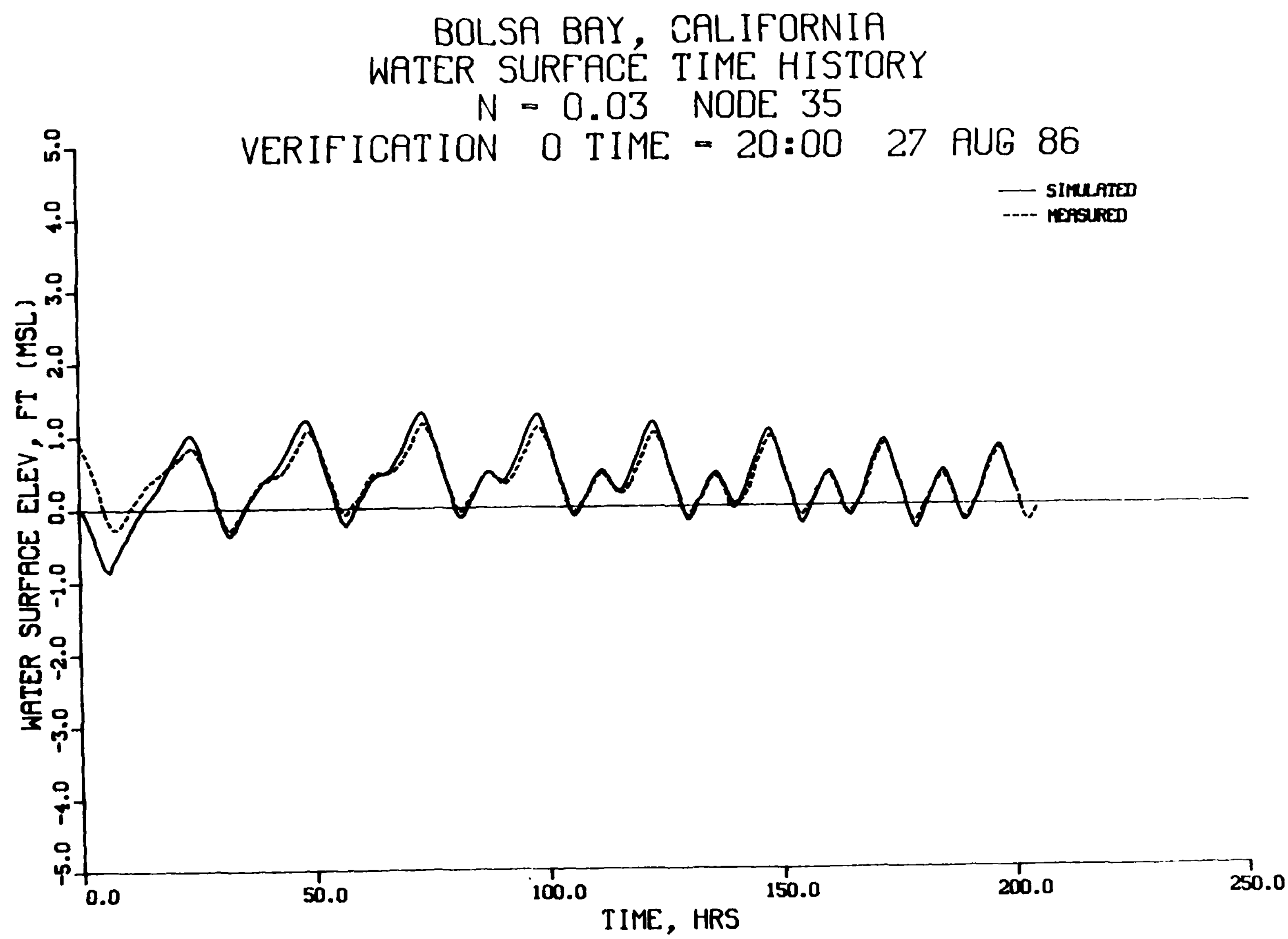


Figure 21. Verification of Inner Bolsa Bay (Node 35), comparison of measured data versus simulation

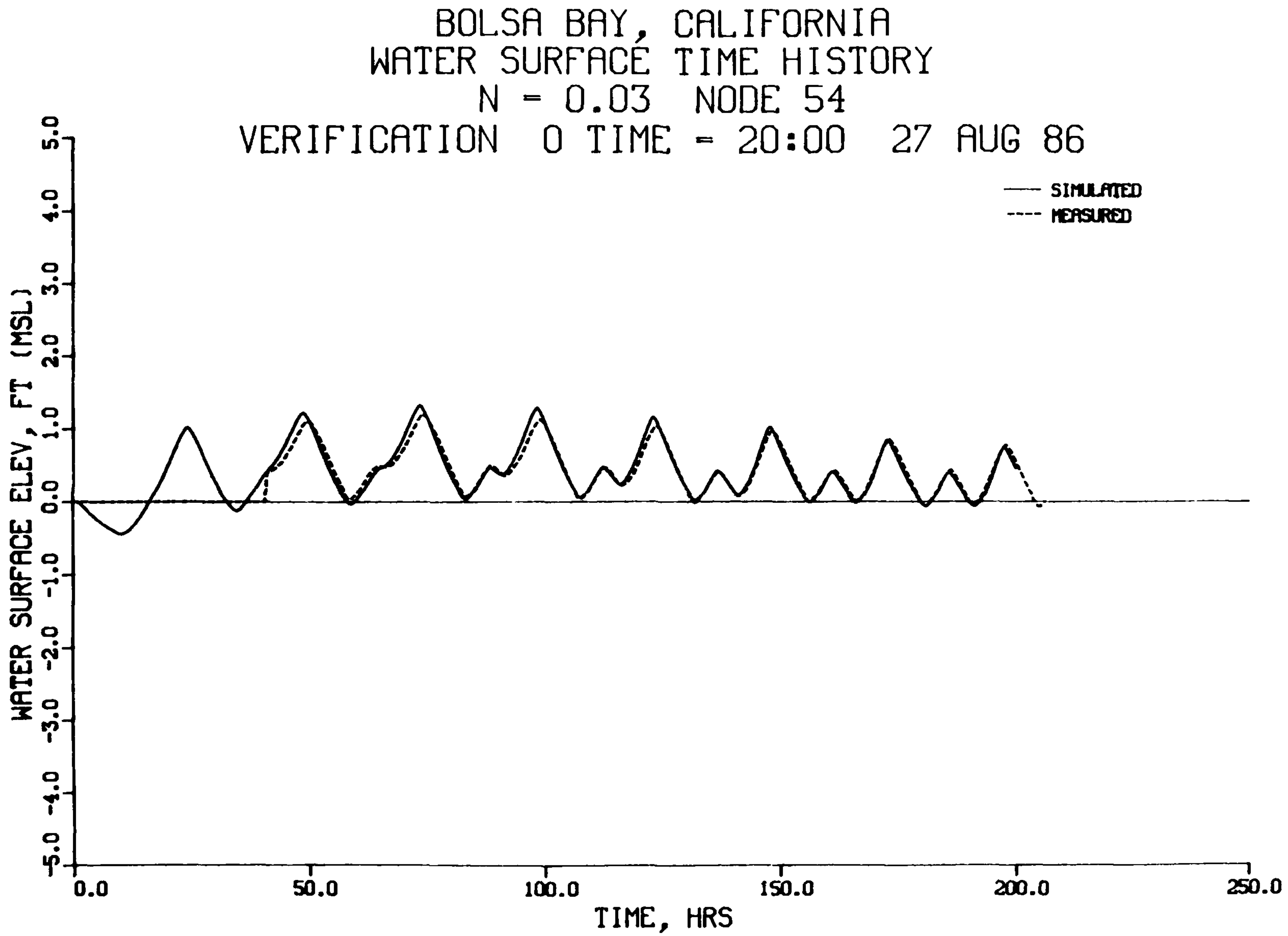


Figure 22. Verification of DFG muted tidal cell (Node 54), comparison of measured data versus simulation

field, since the meter is recording velocity at a point and not deducing an average value for the whole channel section. A comparison of the measured and simulated velocities at Links 7 and 26 are shown in Figures 23 and 24, respectively. Considering the exceedingly good agreement between the water surface elevation simulation and the prototype measurements, and realizing the characteristics of prototype open channel velocities, the velocity comparisons are considered acceptable.

Performance of Calibrated and Verified Model

100. The degree of agreement between the measured and simulated tidal elevations can be defined by the statistical parameters of "bias" and the "RMS error." Bias is the mean difference between the measured and simulated time series over the length of the available record. It is a measure of the systematic error in the computed values. The RMS error is the square root of the average of the squares of the deviations between the measured and simulated time histories. It is a measure of the over-all error, both systematic and random. In all model calibration and verification runs, the time step used was 45 sec. Computed values were saved for plotting purposes at 15-min time intervals. For purposes of this analysis, the measured tidal record is considered the reference datum. Bias is considered positive when the simulation time history has a higher elevation than the measured time history. Bias is considered negative when the simulation time history has a lower elevation than the measured time history. The accuracy of the simulation to both high and low tide elevation (with implications regarding inundation, flooding, and drying of wetlands), for both the calibration and verification periods, are presented in Table 1.

101. As observed in Figures 16 through 18, and 20 through 22, the simulation bias is consistently higher than measured high tide values by about 0.1 ft, and consistently lower than measured low tide values by about 0.05 ft. The RMS values indicate the simulation results consistently deviate from the measured tidal elevations by about 0.1 ft, on the average. Considering the maximum tidal range of about 8 ft, the RMS value of 0.1 constitutes a difference of less than 2 percent. Accordingly, the hydrodynamic numerical

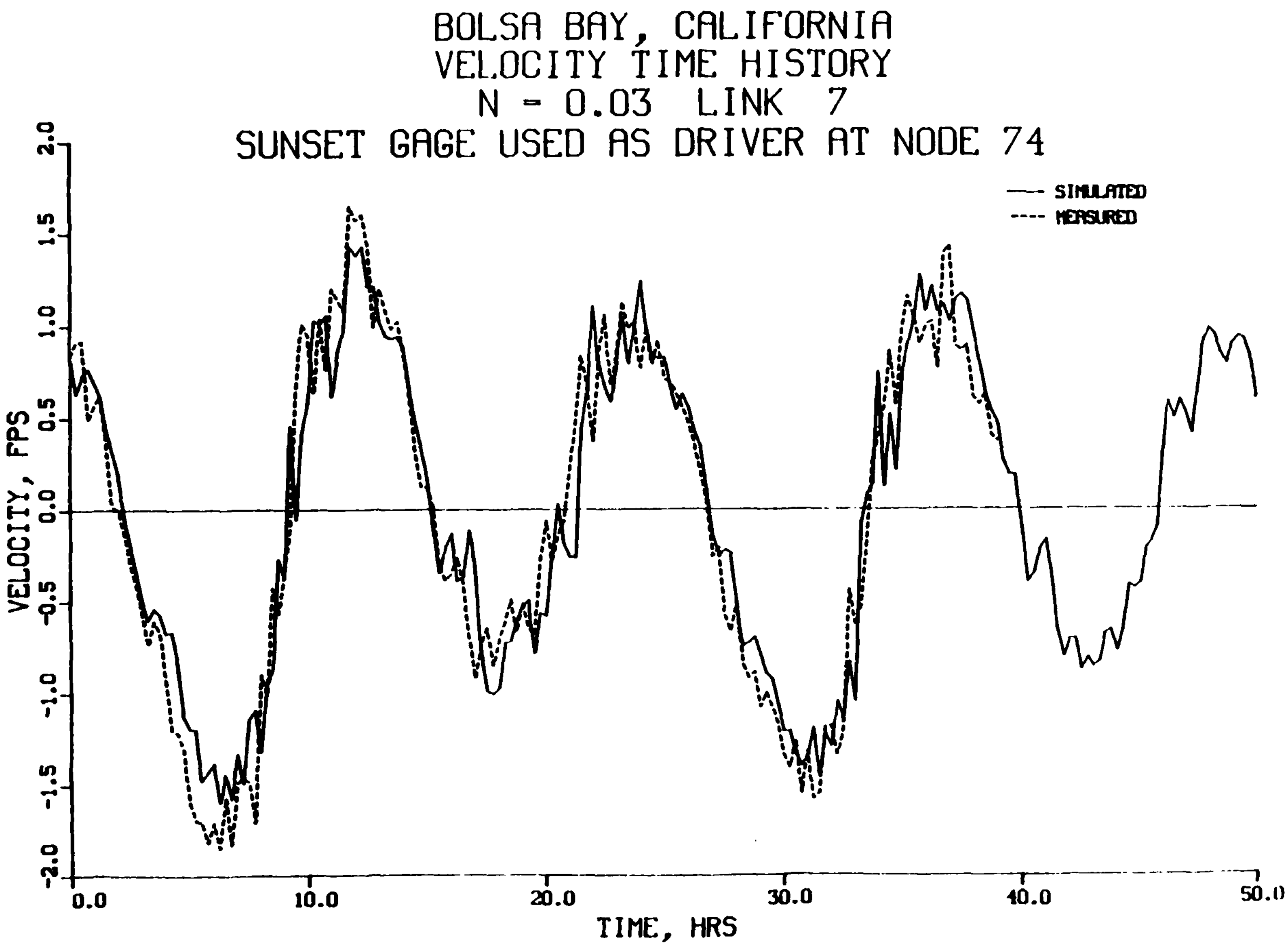


Figure 23. Comparison of measured velocity data versus simulation, Link 7, located in western section of main Huntington Harbour channel

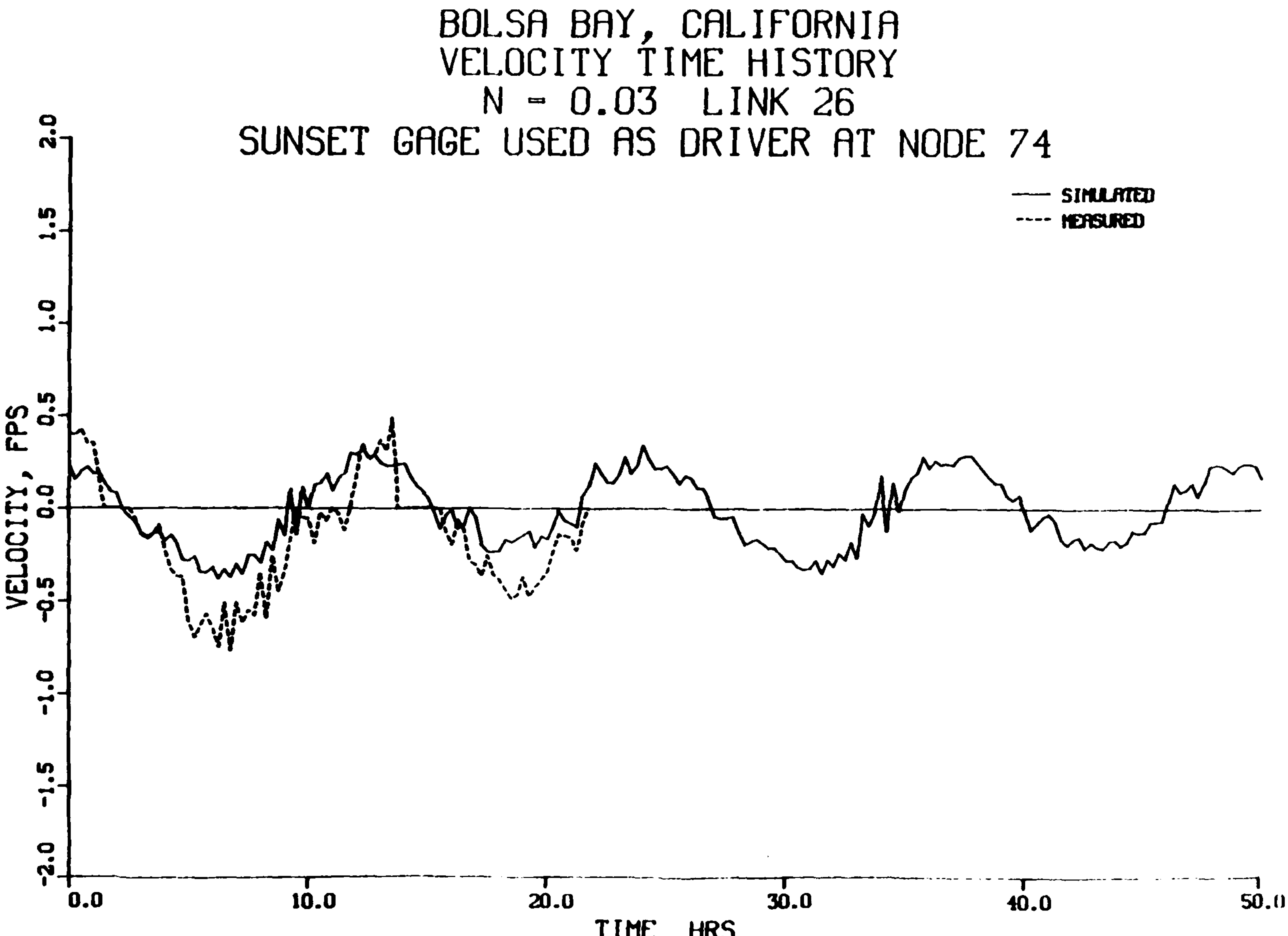


Figure 24. Comparison of measured velocity data versus simulation, Link 26, located in eastern section of main Huntington Harbour channel

Table 1

Deviation Statistics Between Measured and Simulated Tides

Huntington Harbour and Bolsa Bay, California

Location	High Tide Bias feet	High Tide RMS Value feet	Low Tide Bias feet	Low Tide RMS Value feet
Calibration Period				
Sunset Aquatic Park (Node 5)	+0.03	0.04	-0.02	0.03
Outer Bolsa Bay (Node 32)	+0.11	0.12	-0.02	0.11
Inner Bolsa Bay (Node 35)	+0.10	0.11	-0.06	0.09
Verification Period				
Sunset Aquatic Park (Node 5)	+0.02	0.02	+0.01	0.03
Outer Bolsa Bay (Node 32)	+0.08	0.10	-0.10	0.10
Inner Bolsa Bay (Node 35)	+0.13	0.13	-0.08	0.08
DFG muted tidal cell (Node 54)	+0.08	0.10	-0.01	0.03

simulation model portion of DYNTRAN is considered calibrated, verified, and suitable for evaluation of proposed wetland enhancement modifications.

Comparison of Transport Model Results to Field Data

102. To assist in the calibration of the transport model, Tekmarine (1988) was engaged by WES through SPL to conduct field studies of the existing water circulation patterns in the Bolsa Bay complex using dye tracing techniques. The study of the tide-induced circulation patterns involved two dye release and tracking operations, one in Huntington Harbour and the other in Bolsa Bay. Results of this study are presented in Tekmarine (1988), and are summarized in Appendix Q.

103. The one-dimensional solution of the transport equation in DYNTRAN assumes the variation of the constituent concentration within the cross section is small relative to the constituent concentration. The transport

model can not represent the transport of a constituent which displays a large variation of concentrations within the cross section. In a system of relatively narrow unstratified channels such as found in the Bolsa Bay complex, this representation is typically adequate for most constituents. A dye injection for the transport model validation should be well mixed through a cross section and, preferably, through the volume of a model segment. Unfortunately, the initial injection in neither Bolsa Bay nor Huntington Harbour met this criteria.

104. For the Huntington Harbour injection, the data were not satisfactory for model calibration as discussed in greater detail in Appendix Q. However, for the injection in Outer Bolsa Bay, the dye returned on flood flow and provided a well mixed initial condition to compare with model simulations. The initial injection was on the ebb flow and carried into Huntington Harbour, and the dye concentration was measured near the culvert entrance in Outer Bolsa Bay on the returning flood tide. By this time the dye was well mixed, and this return concentration was used as the initial condition for model simulation. Hourly data were collected for approximately 30 hr following the return of the plume on flood flow in Outer Bolsa Bay (Node 33), at two locations in Inner Bolsa Bay (Nodes 37 and 39), and at one location in the new DFG muted tidal cell through the second set of culverts (Node 53). Comparisons of model results and field measurements are shown in Figures 25 through 28.

105. At Node 33 (Figure 25), the model reflects the timing of the oscillations reflected in the measured data. The data is scattered relative to the model predictions, but the general trends are clearly reflected by the model. At Node 37 (Figure 26), the model simulation very slightly lags the data peaks, and the model may be slightly overdispersive. This trend is again reflected at Node 39 (Figure 27). For the collection station in the DFG muted tidal cell (Figure 28), no dye peaks were detected in either the field or transport model.

106. For the Bolsa Bay dye injection study, the model reflects the transport through the first set of culverts and into the wetlands surprisingly well. Since dye concentrations were below detectable levels at the sampling station in the DFG muted tidal cell, no definitive conclusions can be made about transport of material into this back area. However, the model reflects no substantive transport into this area during the field data collection

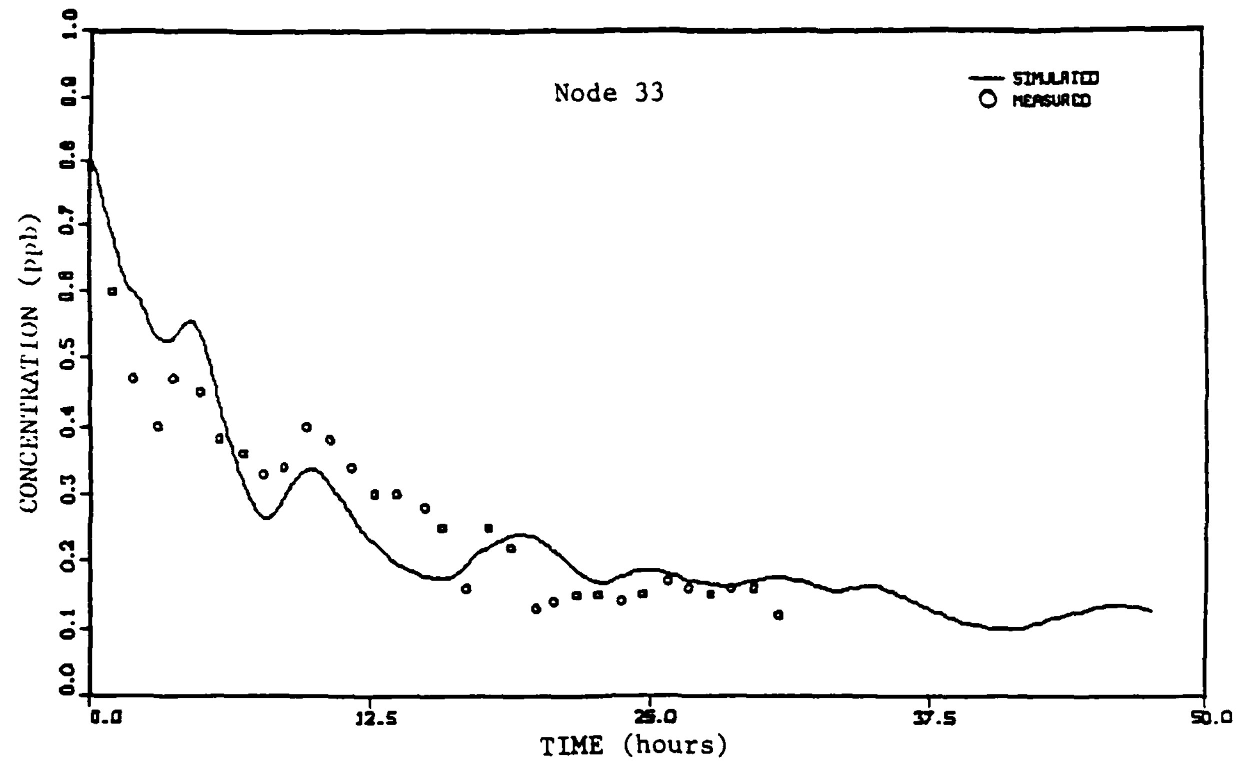


Figure 25. Comparison of transport model results and field dye measurements at Node 33 in Outer Bolsa Bay

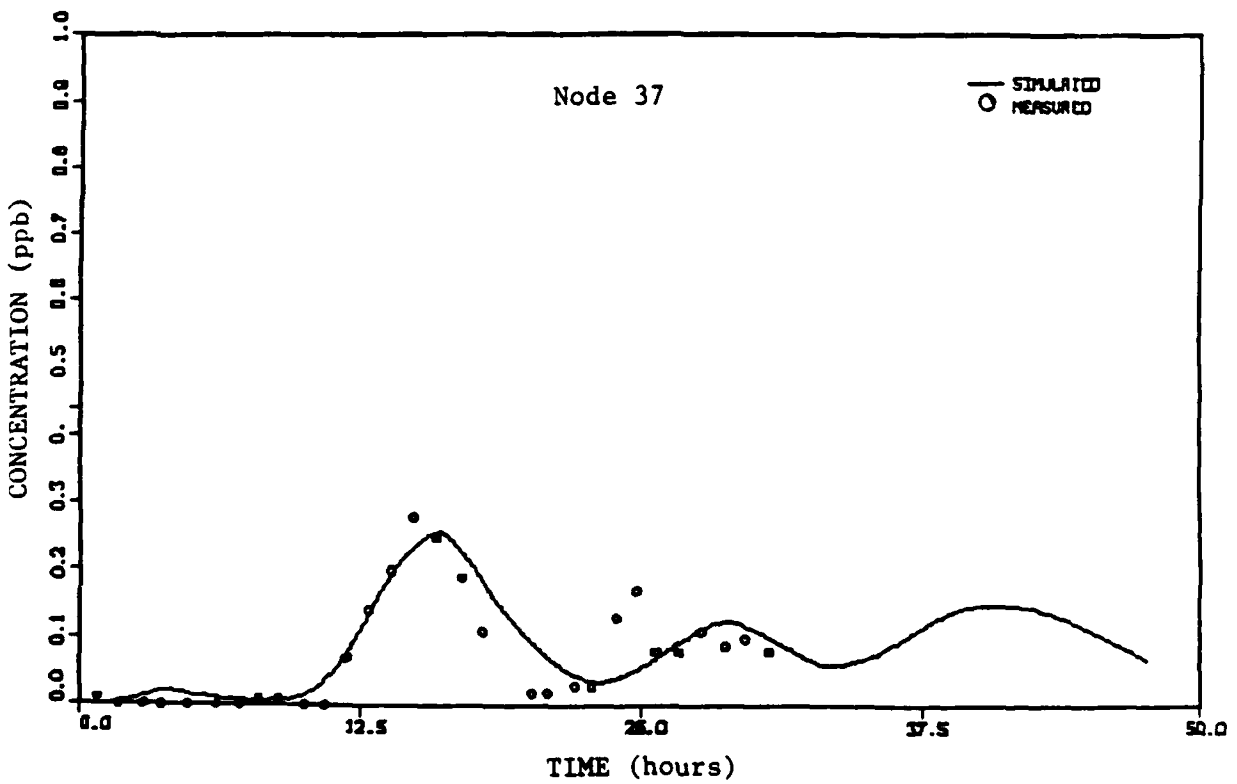


Figure 26. Comparison of transport model results and field dye meaasurements at Node 37 in Inner Bolsa Bay

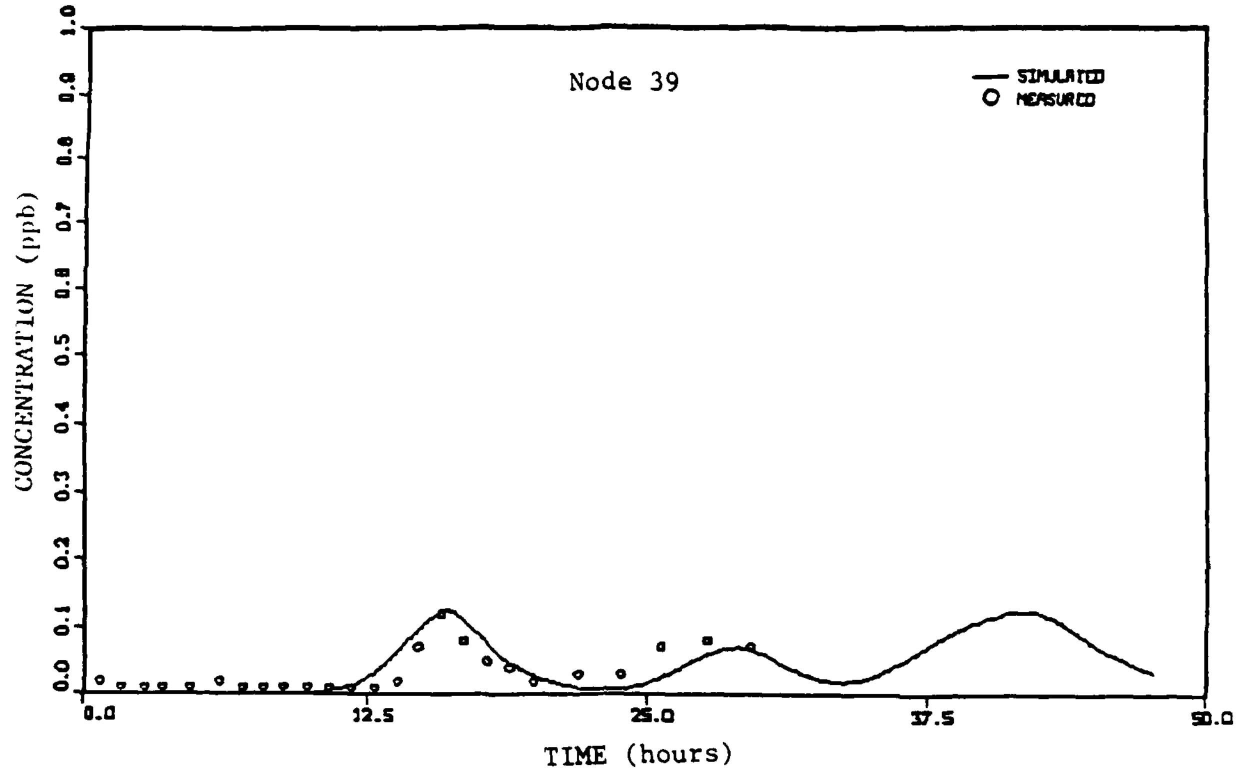


Figure 27. Comparison of transport model results and field dye measurements at Node 39 in Inner Bolsa Bay

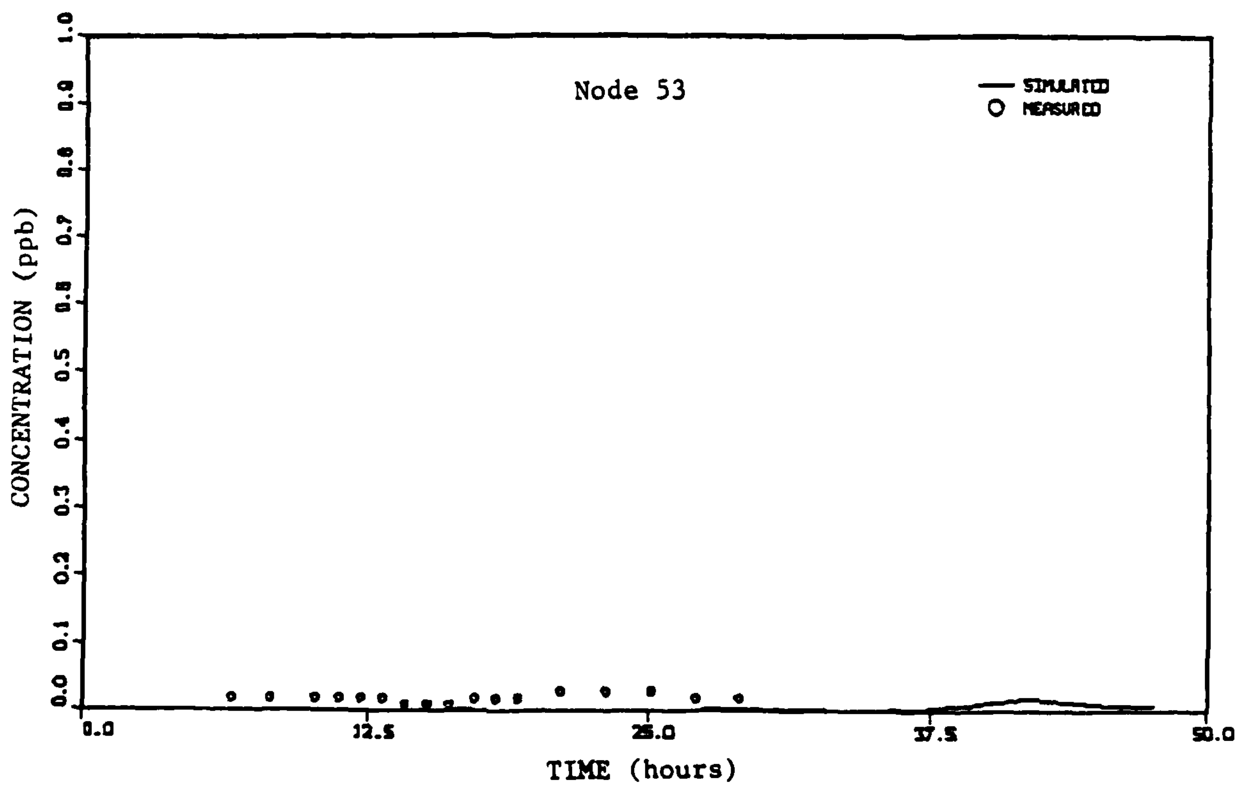


Figure 28. Comparison of transport model results and field dye measurements at Node 53 in DFG muted tidal cell

period.

107. Although the numerical dispersion varies with velocity and channel segment length, an estimate of the order of the numerical dispersion for a "typical segment" in the grid for the Bolsa Bay system provides insight to model performance. For a typical segment of 1,000-ft length, 0.5 ft per sec average velocity, and a model time step of 45 sec, then D_{1n} will be 5.6 ft^2/sec and D_{nu} will be 244 ft^2/sec. The value in the DYNTRAN computation will fall between these two values. Physical dispersion for the system may be estimated using the method described by Fisher et al. (1979). For a channel reach with a width of 200 ft and depth of 10 ft, physical dispersion is on the order of 20 ft^2/sec. Since the model is overdispersive, all transport simulations were performed with 0.0 additional dispersion input to the model. No additional calibration was performed for constituent transport beyond the calibration and verification for the hydrodynamic simulations. It should be understood that the calculation and statement of water age is an artifact of the specific model (characterized by D_{1n} and D_{nu}), and can be used to identify relative changes only. Absolute hours are not necessarily valid or transferable between studies.

PART V: HYDRODYNAMIC EXISTING CONDITIONS

Existing Tides Through the System

108. The developments proposed for Bolsa Bay include marinas and boat berthing facilities, as well as extensive wetland enhancement which includes the restoration of 915 acres of additional wetlands beyond the presently existing 195 acres, with a full or muted tidal range. New entrance channel proposals will alter the existing hydrodynamics of the system. A major part of the restoration program for Bolsa Bay is to restore the degraded areas to specific wetland habitat types, many of which require either a full or muted tide range. The daily rise and fall of the ocean tide creates the flow that brings oxygenated water and nutrients to the wetland system, and is one of the most important characteristics of a wetland (Myrick and Leopold 1963).

109. To evaluate the effectiveness of various alternative proposals for marina development and wetland enhancement at Bolsa Bay, it is necessary to have baseline knowledge and information about the characteristics of the system under existing conditions. After the hydrodynamic simulation model **DYNTRAN** had been calibrated and verified with measured prototype field data at specific locations within the region of interest, the model was then ready to simulate baseline (existing conditions) throughout the system complex.

110. A tidal signal was desired which covered a wide range. For the baseline (existing condition) simulation, the tidal constituents which summed to create the prototype tide for the time period of numerical model calibration (16-28 August 1986) were chosen. This period consisted of tides which varied from spring range of around 8 ft, through the average tidal range of about 5 ft, to a neap tide condition with ranges of approximately 3.5 ft. Because tidal constituents were utilized in the simulations, the short-period oscillations recorded at Sunset Aquatic Park do not appear in either the baseline simulations nor any plan condition simulations.

111. It was known a priori that changes would occur under plan conditions to both tide levels and velocities at specific locations. Hence, the link-node system was developed to access data at critical positions. Although tidal data were obtained at all nodes of the system, only typical displays at a representative node in Huntington Harbour (Node 10), Outer Bolsa Bay

(Node 32), Inner Bolsa Bay (Node 37), and the DFG muted tidal cell (Node 54) shown on Figure 29 are presented in Figures 30 through 33, respectively. Displays of water surface time histories for existing conditions at nodes throughout the bay complex are presented in Appendix A.

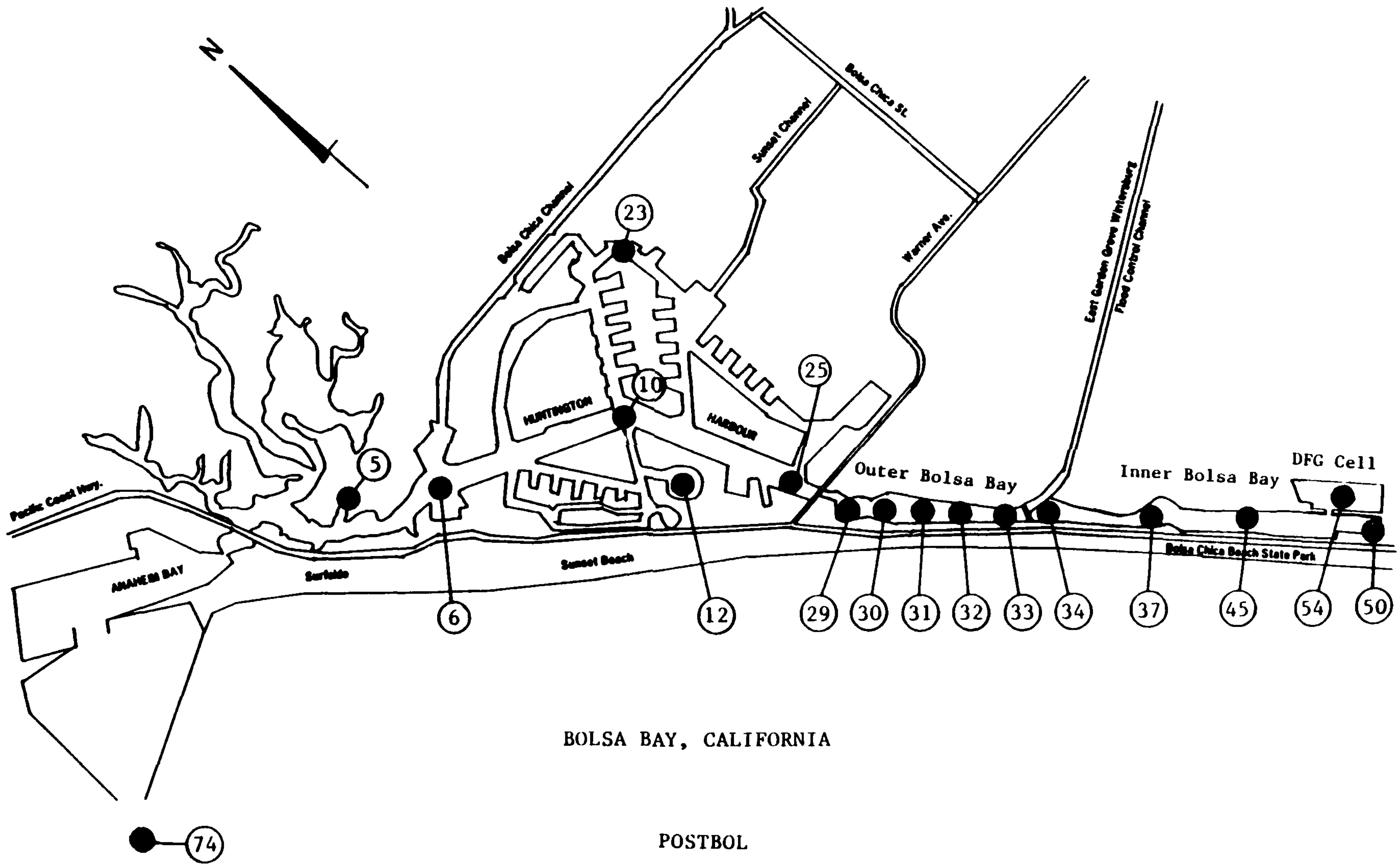
112. Tidal ranges in Huntington Harbour were found to exist almost exactly as the ocean tide because of the absence of significant restrictions to flow. Tides will continue to achieve maximum magnitudes in Huntington Harbour under all proposed entrance channel configurations. Under certain proposed changes, the tide may fall to a lower elevation in Outer Bolsa Bay than at present; hence, it was desired to know the existing tide ranges throughout Outer Bolsa Bay. It was stipulated by SLC that tide ranges in Inner Bolsa Bay should remain essentially unaltered for all plan alternatives. Tidal ranges for existing conditions at representatives nodes are presented in Table 2. Existing conditions subsequent to construction of the DFG muted tidal cell are designated POSTBOL.

Table 2

POSTBOL
Existing Condition

Tide Ranges at Representatives Nodes

Location	Node No	High Tide feet, msl	Low Tide feet, msl
Huntington Harbour	10	4.10	-4.09
Outer Bolsa Bay	29	4.10	-3.87
Outer Bolsa Bay	30	4.10	-2.88
Outer Bolsa Bay	31	4.10	-2.77
Outer Bolsa Bay	32	4.10	-2.47
Outer Bolsa Bay	33	4.10	-2.02
Inner Bolsa Bay	34	1.04	-0.39
Inner Bolsa Bay	37	1.04	-0.40
Inner Bolsa Bay	45	1.04	-0.36
Inner Bolsa Bay	50	1.04	-0.36
DFG muted tidal cell	54	0.98	-0.09



BOLSA BAY, CALIFORNIA

POSTBOL

Figure 29. Location of nodes for displaying tidal elevations under existing conditions

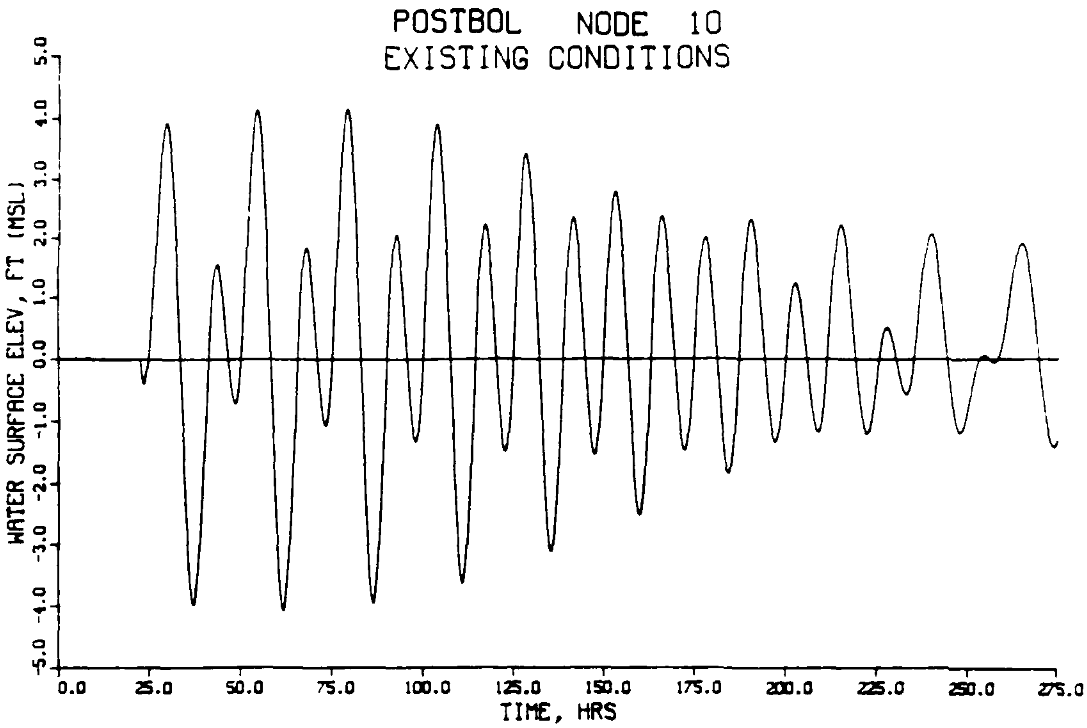


Figure 30. Tidal elevations in Huntington Harbour under existing conditions, POSTBOL

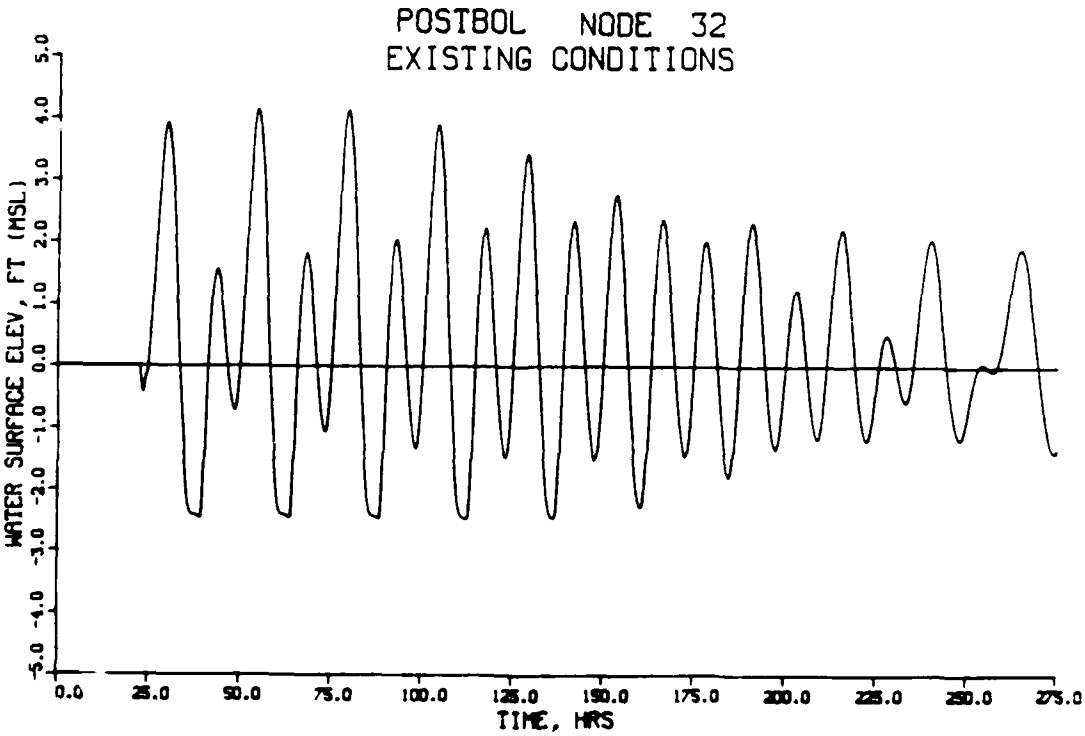


Figure 31. Tidal elevations in Outer Bolsa Bay under existing conditions, POSTBOL

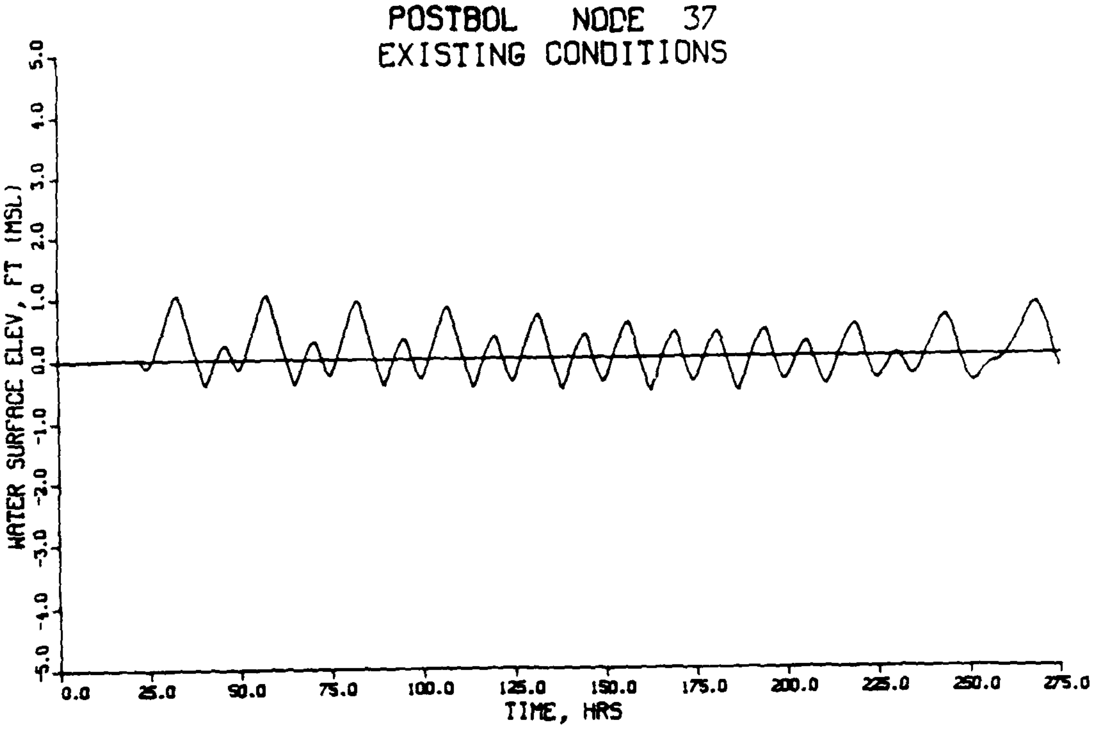


Figure 32. Tidal elevations in Inner Bolsa Bay under existing conditions, POSTBOL

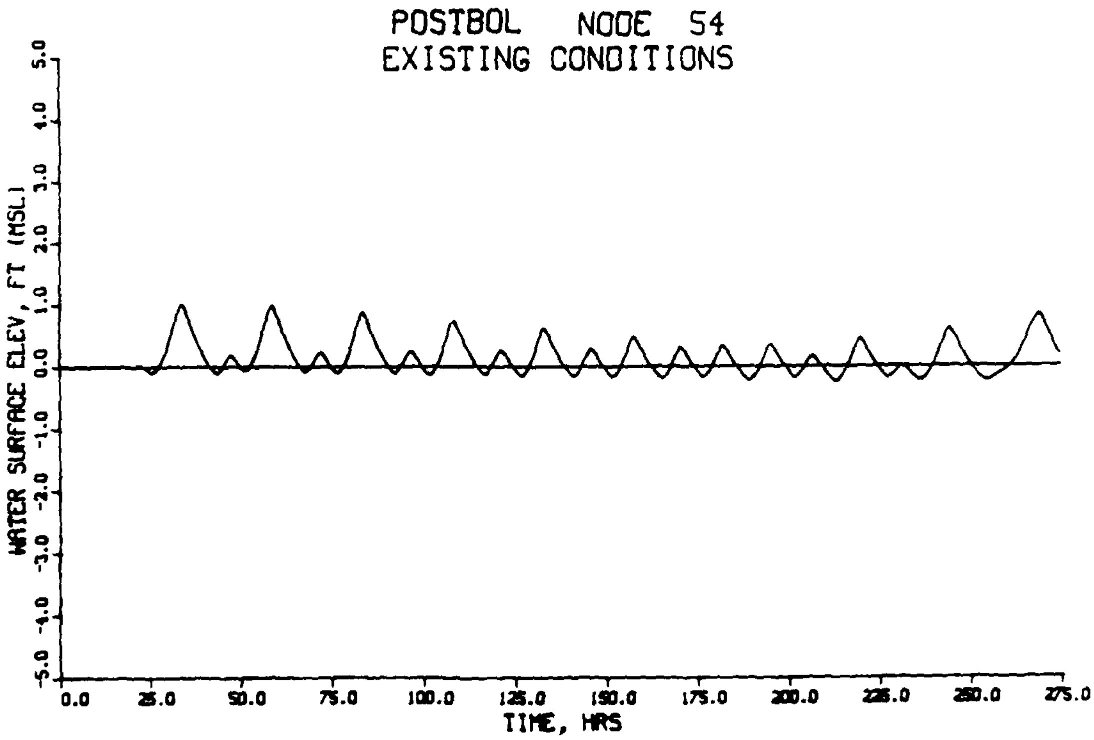
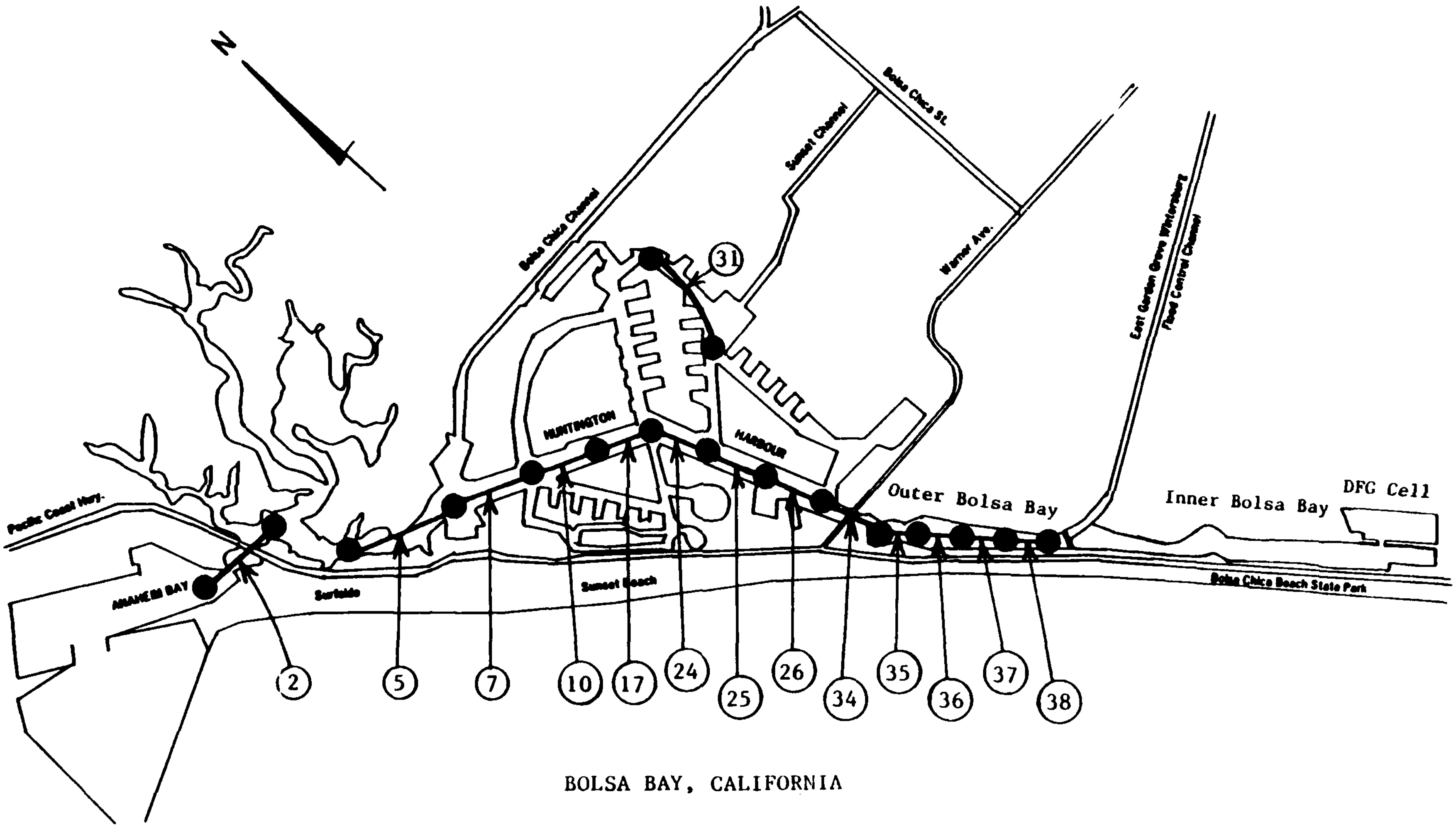


Figure 33. Tidal elevations in DFG muted tidal cell under existing conditions, POSTBOL

Existing Velocities Through the System

113. Because new entrance channel concepts could have the potential for increased velocities through Outer Bolsa Bay, with possible scouring effects, it is desired to understand the effects of proposed plans on velocities in this region. Similarly, a large influx of tidal water through a new entrance channel will interact with flows from Anaheim Bay, and a region of reduce average velocities may occur, though not necessarily an adverse impact.

114. Design criteria pertaining to velocity are also pertinent from the standpoint of swimmer safety in Huntington Harbour, and navigation of small craft under the PCH bridge. Average channel velocities through Huntington Harbour are simulated precisely by DYNTRAN; however, the helical and spiral flow traveling a curvilinear path on its approach to, and exit from, the bridge is not entirely simulated. Maximum values of velocity under PCH bridge will be greater than simulated, and relative values only of velocity increase or decrease will be obtained. While average channel velocities were estimated for all links of the bay complex system (Figure 34), only typically representative examples are presented in Figures 35 through 40 for example velocity displays in Huntington Harbour (Links 7, 17, and 26), under Warner Avenue bridge (Link 34), and in Outer Bolsa Bay (Links 36 and 38), respectively. Maximum average channel velocities for all links along the main Huntington Harbour channel and Outer Bolsa Bay are presented in Table 3. Displays of average channel velocity time-histories for pertinent links through Huntington Harbour and Outer Bolsa Bay are presented in Appendix B.



BOLSA BAY, CALIFORNIA

POSTBOL

Figure 34. Location of links for displaying average channel velocities under existing conditions

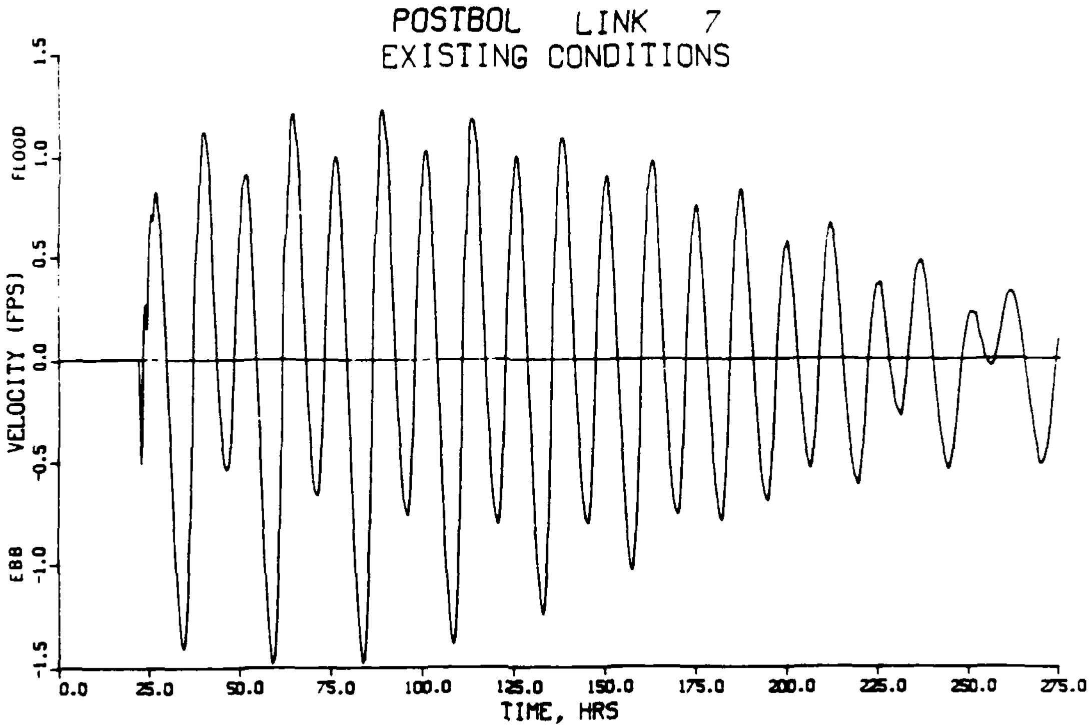


Figure 35. Average channel velocities in Huntington Harbour under existing conditions, POSTBOL

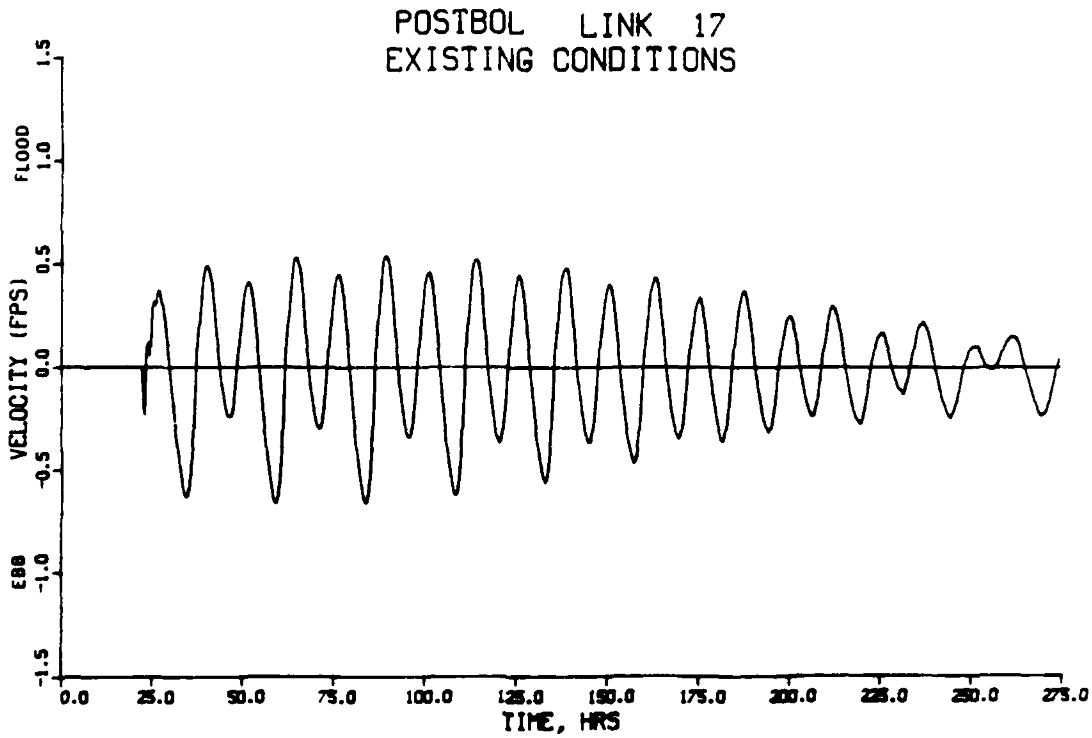


Figure 36. Average channel velocities in Huntington Harbour under existing conditions, POSTBOL

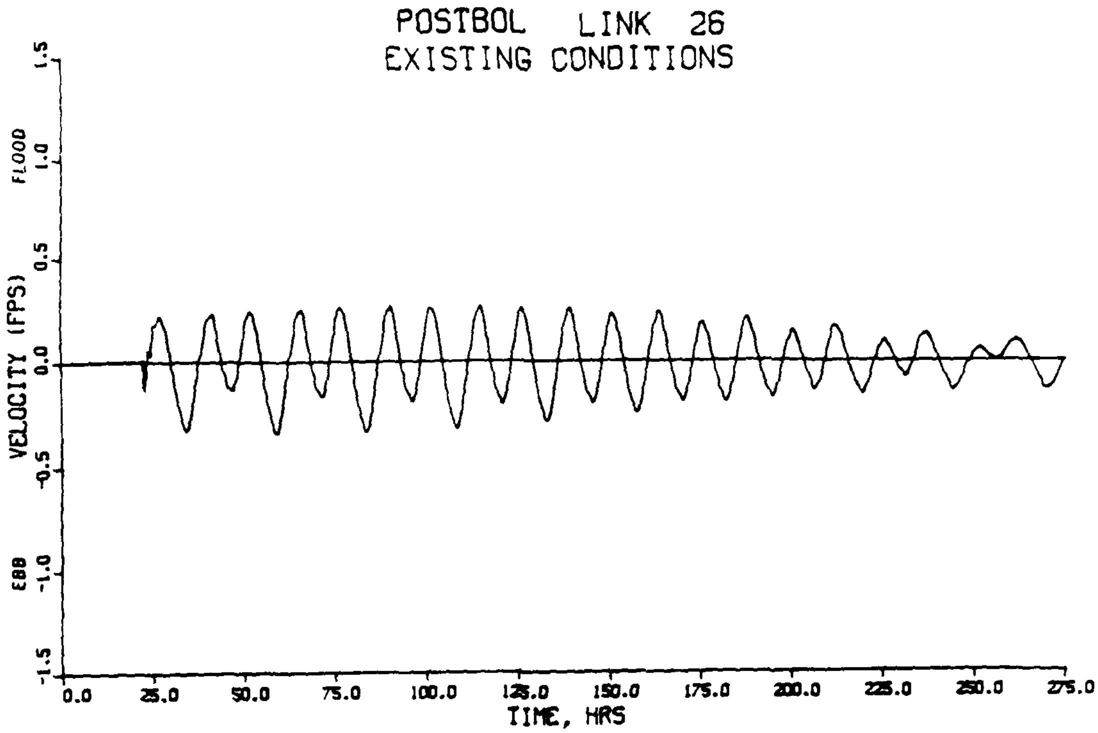


Figure 37. Average channel velocities in Huntington Harbour under existing conditions, POSTBOL

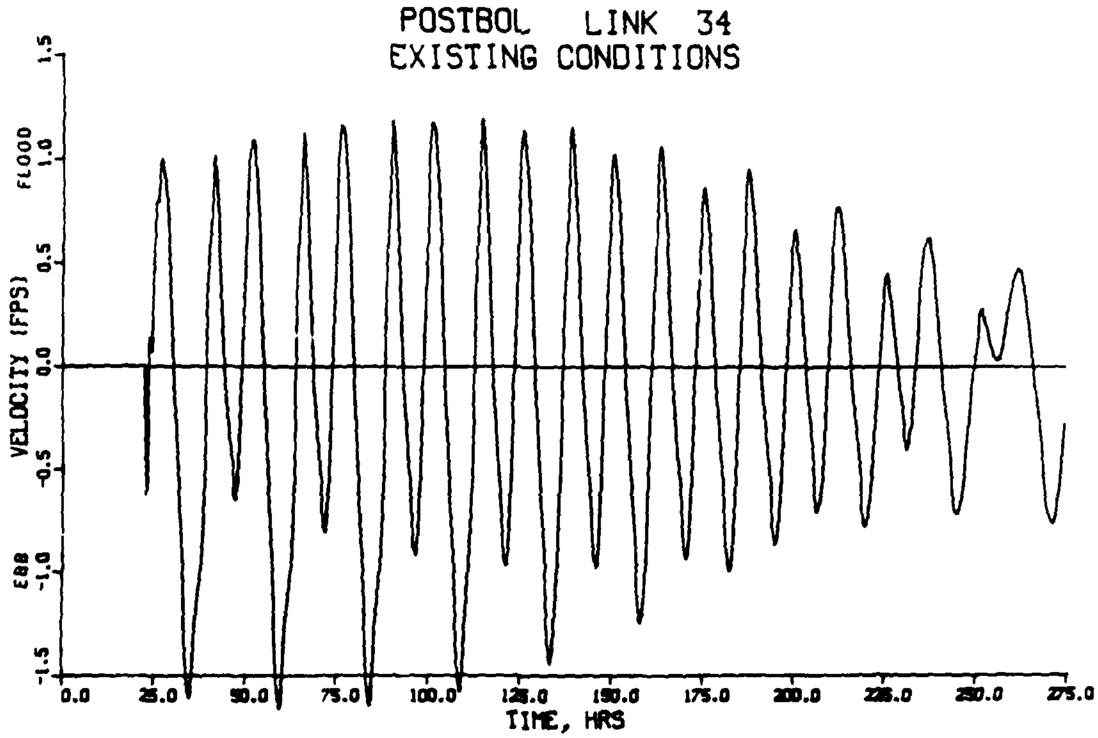


Figure 38. Average channel velocities at Warner Avenue Bridge under existing conditions, POSTBOL

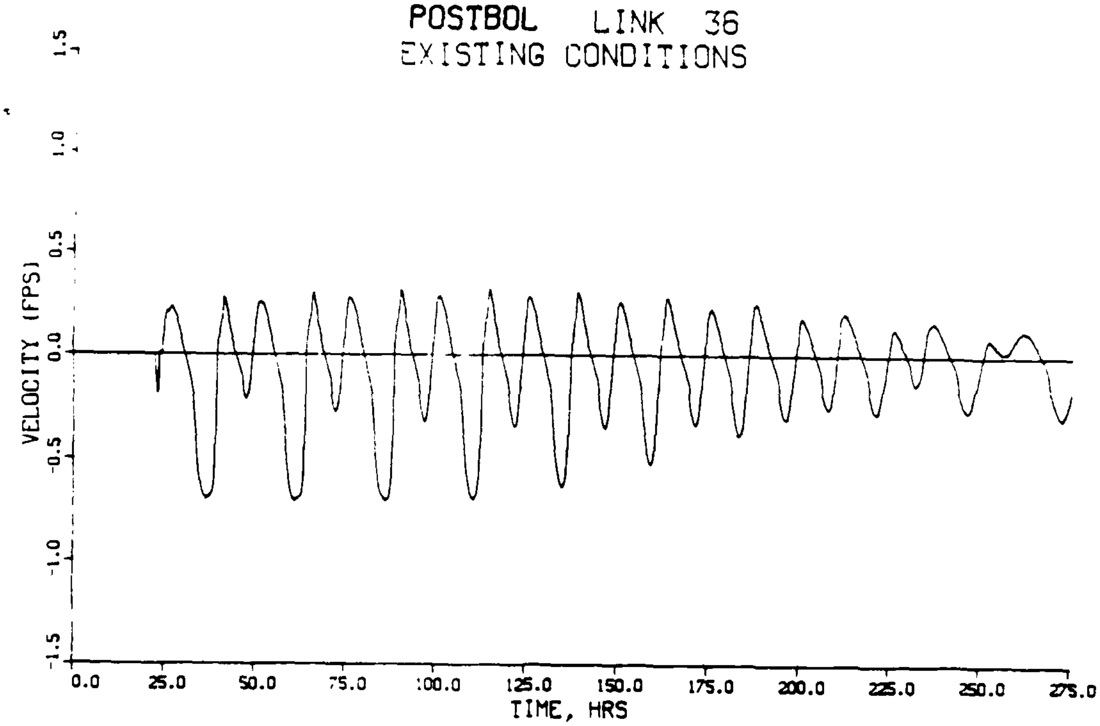


Figure 39. Average channel velocities in Outer Bolsa Bay under existing conditions, POSTBOL

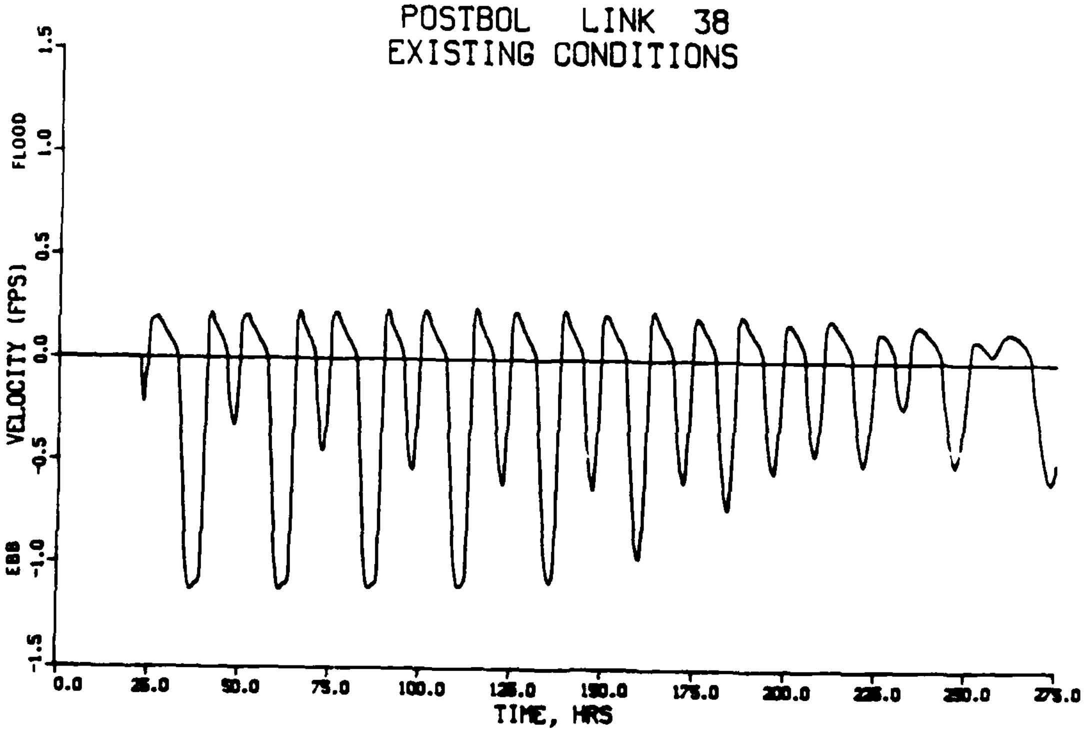


Figure 40. Average channel velocities in Outer Bolsa Bay under existing conditions, POSTBOL

Table 3

POSTBOL
Existing Condition

Maximum Average Channel Velocities Along Main Channel System

Location	Link No	Maximum Average Channel Velocity ft per sec
Pacific Coast Highway bridge	2	2.78
Huntington Harbour	5	1.42
Huntington Harbour	7	1.48
Huntington Harbour	10	0.71
Huntington Harbour	17	0.66
Huntington Harbour	24	0.57
Huntington Harbour	25	0.30
Huntington Harbour	26	0.34
Warner Avenue bridge	34	1.65
Outer Bolsa Bay	35	1.35
Outer Bolsa Bay	36	0.71
Outer Bolsa Bay	37	0.88
Outer Bolsa Bay	38	1.12

PART VI: *NAVIGABLE ENTRANCE CHANNEL CONCEPT*

115. The revised Bolsa Chica Local Coastal Program Land Use Plan (LUP) was prepared by the Orange County Environmental Management Agency (1985), is in full agreement with, and contains all suggested modifications approved by the CCC on 23 October 1985. The new entrance channel concept (Preferred LUP Alternative) provides for multiple and naturally supportive uses with an emphasis on wildlife habitat enhancement, public recreation, coastal access, and water dependent residential development.

116. The Bolsa Chica LUP closely reflects the land use allocations configurations agreed to in 1984 by the Habitat Conservation Plan participants, including (a) the Coastal Conservancy, (b) the California Department of Fish and Game, (c) the County of Orange, and (d) one landowner, Signal Bolsa Corporation. The LUP Preferred Alternative includes the following features, among others:

a. 915 acres of restored, high quality, fully functioning full tidal, muted tidal, fresh, and brackish water wetlands within the study area, with emphasis on diversity of habitat and protection and recovery of endangered species,

b. 86 acres of existing or newly created environmentally sensitive habitat within the study area,

c. A fully-navigable ocean entrance to provide a continuous, assured source of water for tidal wetlands and interior waterways, and for recreational boating ocean access from both the Bolsa Chica area and Huntington Harbour, and

d. Interior navigable waterways providing navigable connections the Bolsa Chica marina, waterfront residential housing, and potentially to the Huntington Harbour area.

Wetland Design

117. Based on the requirements of converting non-wetlands into wetland status according to LUP policies, DFG (Radovich 1987) determined the minimum acreage requirements per wetland type as:

a. High pickleweed dominated saltmarsh (rarely, if ever, completely inundated), 200 acres,

b. Periodically inundated saltflats, 150 acres,

c. Fresh to slightly brackish (less than 5 ppt salts) permanently inundated pond, 50 acres,

d. Muted tidal wetland (similar to that contained within Inner Bolsa Bay) with an 18-in. daily average tidal water level variance, 300 acres,

e. Full tidal wetland (similar to that contained within Outer Bolsa Bay), 215 acres, and

f. Total wetland acreage, 915 acres.

118. Accordingly, Moffatt & Nichol, Engineers, in 1988, analyzed the geometry of the study area based on these criteria. The tidal wetlands evaluated consisted of 142 acres of existing full and muted tidal wetlands, 116 acres of proposed additional full tidal wetlands, and 193 acres of proposed additional muted tidal wetlands. Their storage curves are:

<u>Existing Full and Muted Tidal Wetlands</u>

Elevation (ft, msl)	-3.5	-2.3	-0.3	1.8	4.5
Area (acres)	1.7	6.3	44.4	122.6	142.0

<u>Proposed Additional Full Tidal Wetlands</u>

Elevation (ft, msl)	-5.0	0.0	1.0	2.0	4.5
Area (acres)	58.2	96.5	100.6	105.3	116.0

<u>Proposed Additional Muted Tidal Wetlands</u>

Elevation (ft, msl)	-3.5	-2.3	-0.3	1.8	4.5
Area (acres)	2.3	8.6	60.5	167.0	193.4

These data also were developed contingent upon the requirement that a minimal amount of earth moving take place in the wetland enhancement area. The storage curves for these wetlands are displayed in Figure 41, and the plan layout is shown in Figure 42. The wetland design will remain the same for the Preferred Alternative (navigable entrance channel) with or without a navigable connector channel to Huntington Harbour. The above elevation-area relationships were installed in the numerical model for all proposed wetland designs.

Culvert System Design

119. Preliminary evaluations have resulted in specific culvert designs which are being utilized, in conjunction with marina and wetland enhancement alternatives. These simulations will assess the effectiveness of the culverts

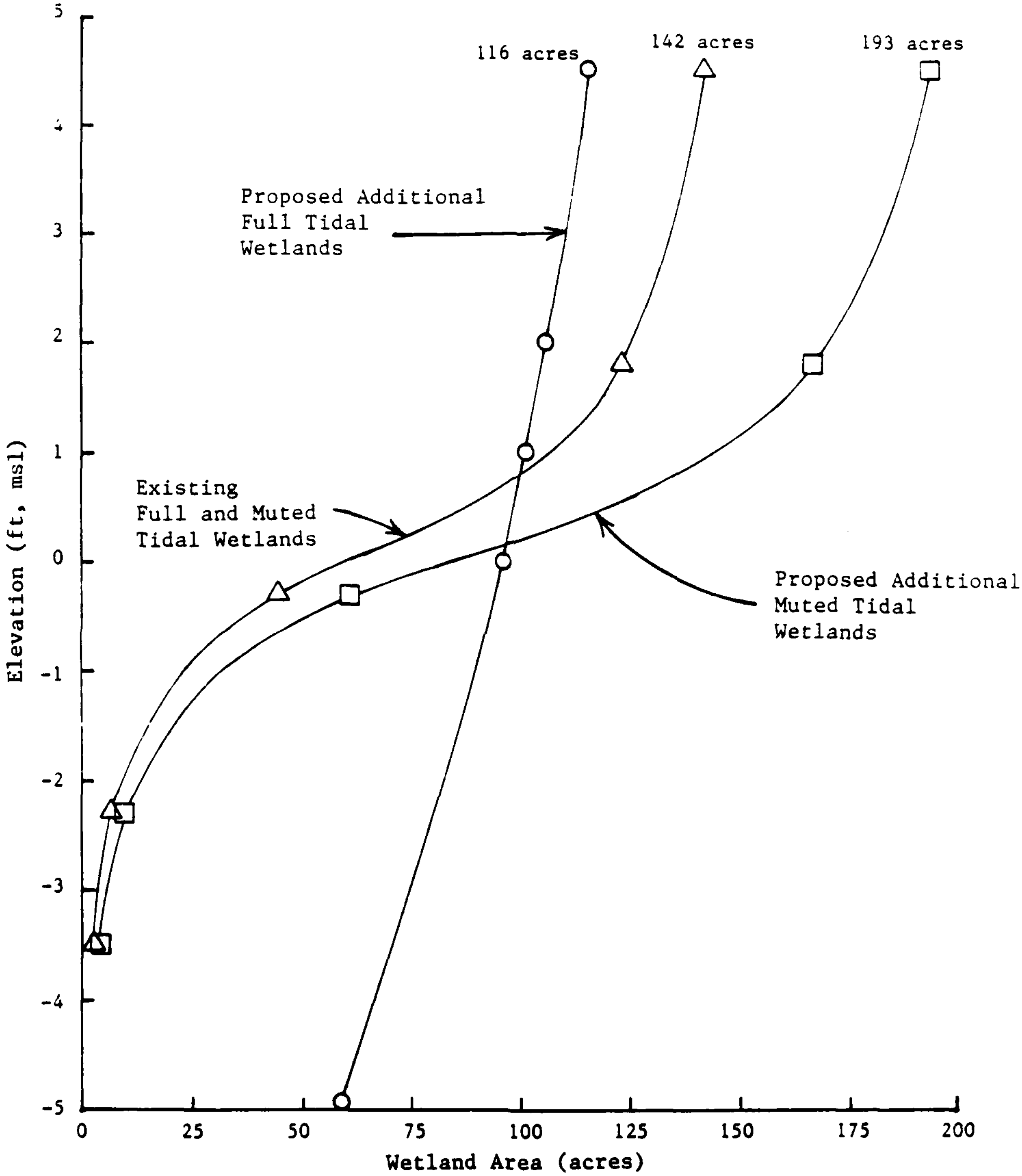


Figure 41. Elevation-area relationship of existing and proposed wetland enhancement areas, navigable entrance channel concept, NENC

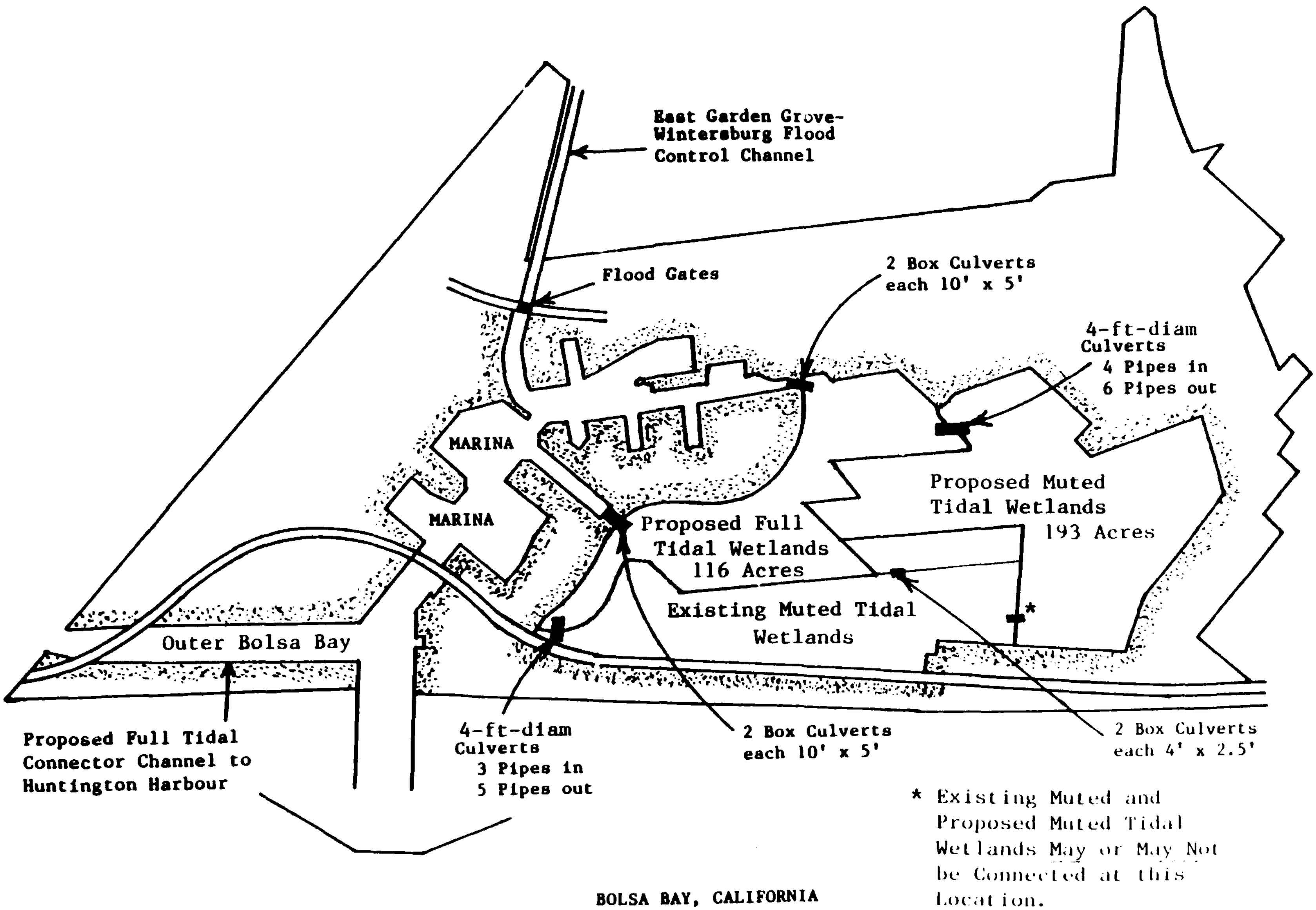


Figure 42. Preferred Alternative, navigable entrance channel with navigable connector channel to Huntington Harbour concept, NENC, and proposed wetland enhancement areas

in providing an assured level of wetland inundation and flushing ability.

120. The navigable entrance channel concept (with or without a navigable connector channel to Huntington Harbour) provides for connecting the marinas with a full tidal wetland region by two box culvert systems. Each of the culvert systems will have two box culverts, each 5-ft high by 10-ft wide at an invert elevation of -5 ft msl. The full tidal wetland region is then connected to a muted tidal wetland region by a 4-ft-diam culvert system (4 pipes in, 6 pipes out). The full tidal wetland region is also connected to the existing Inner Bolsa Bay by a 4-ft-diam culvert system (3 pipes in, 5 pipes out). Both of these culvert systems have invert elevations of -5.1 ft msl.

NENC
Navigable Entrance Channel and Navigable Connector Channel to Huntington Harbour

Entrance channel characteristics

121. Based on guidance for small craft harbor design, construction, and operation (Dunham and Finn 1974), and on practical experience and applications along the southern California coast, SLC developed criteria for WES to install in both the numerical model DYNTRAN and the physical hydraulic model. These data included dimensions of the navigable entrance channel, navigable connector channel to Huntington Harbour, and proposed marina characteristics.

122. The entrance channel from the Pacific Ocean into Bolsa Bay was determined to require a bottom width of 800 ft at a bottom elevation of -23 ft msl, based on anticipated boating demand from both the proposed marina complex and existing Huntington Harbour utilization. The dimensions of the navigable connector channel to Huntington Harbour were established with a bottom width of 350 ft at a bottom elevation of -14.8 ft msl. The width of the main channel through the proposed marina complex varied from about 350 ft near the ocean entrance, to about 200 ft near its confluence with the two proposed new wetland culvert systems. The bottom elevation of the main marina channel was determined to be -20 ft msl.

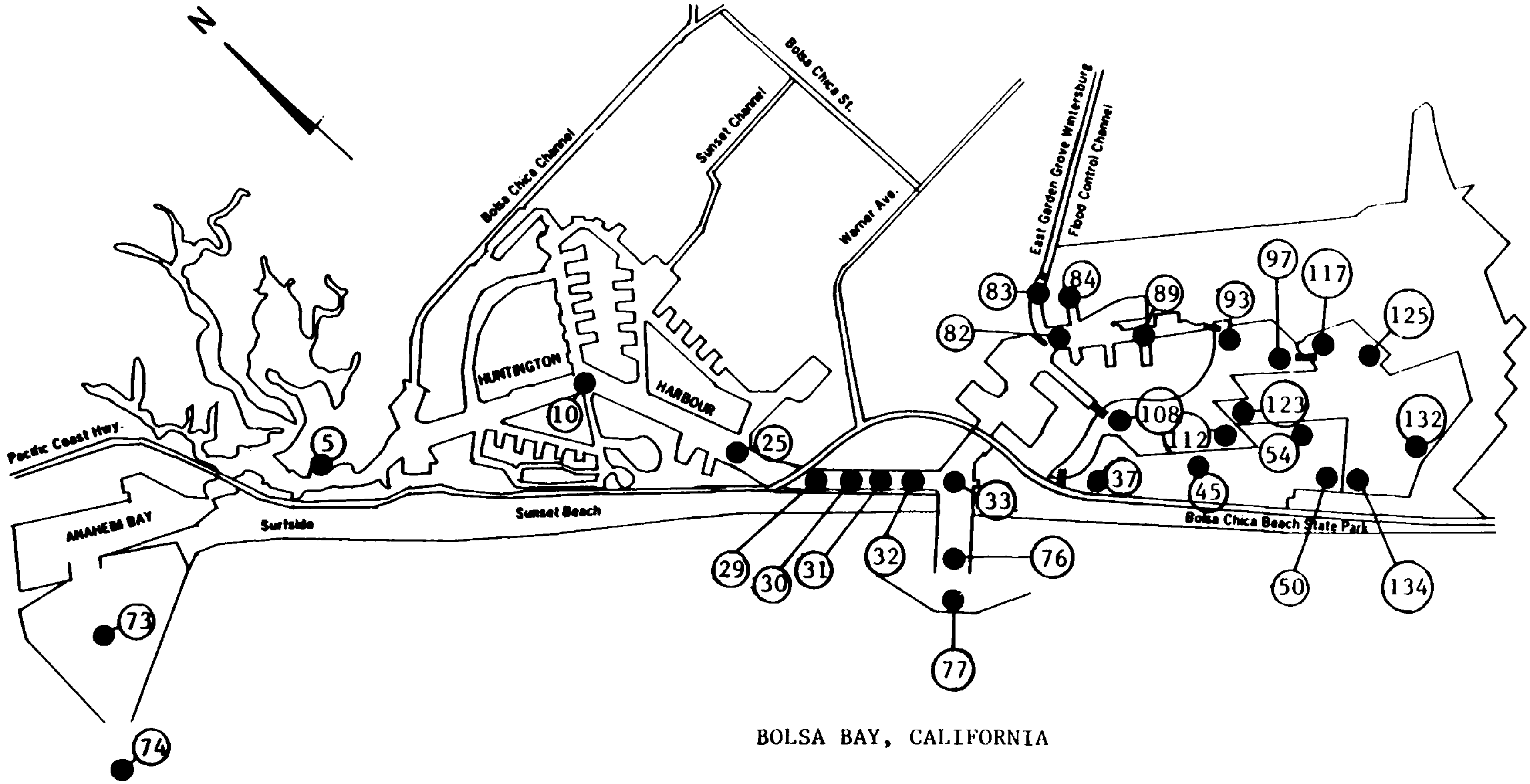
Tidal elevations

123. Tidal simulations throughout the Bolsa Bay complex for the navigable entrance channel with a navigable connector channel to Huntington Harbour (NENC1) concept (Figure 43) are displayed in Appendix C. Tidal ranges at representative regions throughout the bay system are presented in Table 4. These regions includes Huntington Harbour, Outer Bolsa Bay, Inner Bolsa Bay, and the proposed wetland enhancement design. The effect of the NENC1 concept on typically representative water surface elevation time-histories are presented in Figures 44 through 47 for Huntington Harbour (Node 10), Outer Bolsa Bay (Node 32), Inner Bolsa Bay (Node 37), and the DFG muted tidal cell (Node 54), respectively. Time-histories of water surface elevations for the proposed marina (Node 89), proposed full tidal wetland areas (Node 93), and proposed muted tidal wetland areas (Node 132), are shown in Figures 48 through 50, respectively.

124. Because of the wide, deep channels which were installed in the proposed new entrance channel and through Outer Bolsa Bay, Huntington Harbour tidal prism enters and leaves partially through the new entrance and partially by way of existing Anaheim Bay. The harbor previously filled to capacity from flow through Anaheim, so the new entrance channel at Bolsa Bay has negligible contribution to the already adequate water surface elevation fluctuations in Huntington Harbour. The deep basins of the proposed marina and channel through the marina complex also respond directly as the nearby ocean entrance.

125. The culvert system presently under consideration allows a slight increase in high tide elevation in both Inner Bolsa Bay and the DFG muted tidal cell, as compared to existing conditions. Low tidal elevations for this plan approximate the existing low tide elevations throughout Inner Bolsa Bay and the DFG muted tidal cell. Tide gates and culvert system operation can be optimized to provide any reasonable degree of inundation (within maximum limits) desired in this controlled environment.

126. The regions of proposed full tidal wetland enhancement, and proposed muted tidal wetland enhancement, do not presently exist; hence, there are no existing data with which to compare these tidal fluctuations. It is apparent, however, that there is about a 50 percent reduction in tidal range between the marina channels and the full tidal wetland, and around another



BOLSA BAY, CALIFORNIA

NENC

Figure 43. Location of nodes for displaying water surface elevations under navigable entrance channel and navigable connector channel to Huntington Harbour conditions

Table 4

NENC1
Navigable Entrance Channel
and Navigable Connector Channel to Huntington Harbour

Wetlands Connected

Tide Ranges at Representatives Nodes

Location	Node No	High Tide feet, msl	Low Tide feet, msl
Huntington Harbour	10	4.10	-4.09
Outer Bolsa Bay	29	4.10	-4.03
Outer Bolsa Bay	30	4.10	-4.03
Outer Bolsa Bay	31	4.09	-4.02
Outer Bolsa Bay	32	4.09	-4.02
Outer Bolsa Bay	33	4.09	-4.02
Inner Bolsa Bay	37	1.40	-0.43
Inner Bolsa Bay	45	1.40	-0.43
Inner Bolsa Bay	50	1.40	-0.43
DFG muted tidal cell	54	1.34	0.01
Proposed marina	89	4.09	-4.02
Proposed full tidal wetlands	93	3.08	-0.86
Proposed full tidal wetlands	108	3.08	-0.86
Proposed muted tidal wetlands	123	1.41	-0.39
Proposed muted tidal wetlands	132	1.41	-0.38

50 percent reduction in tidal range between the full tidal wetlands and the muted tidal wetlands. Here again, the tide gate system operation can be adjusted to provide any desired level of tidal range and low tide elevations, (within reasonable limits).

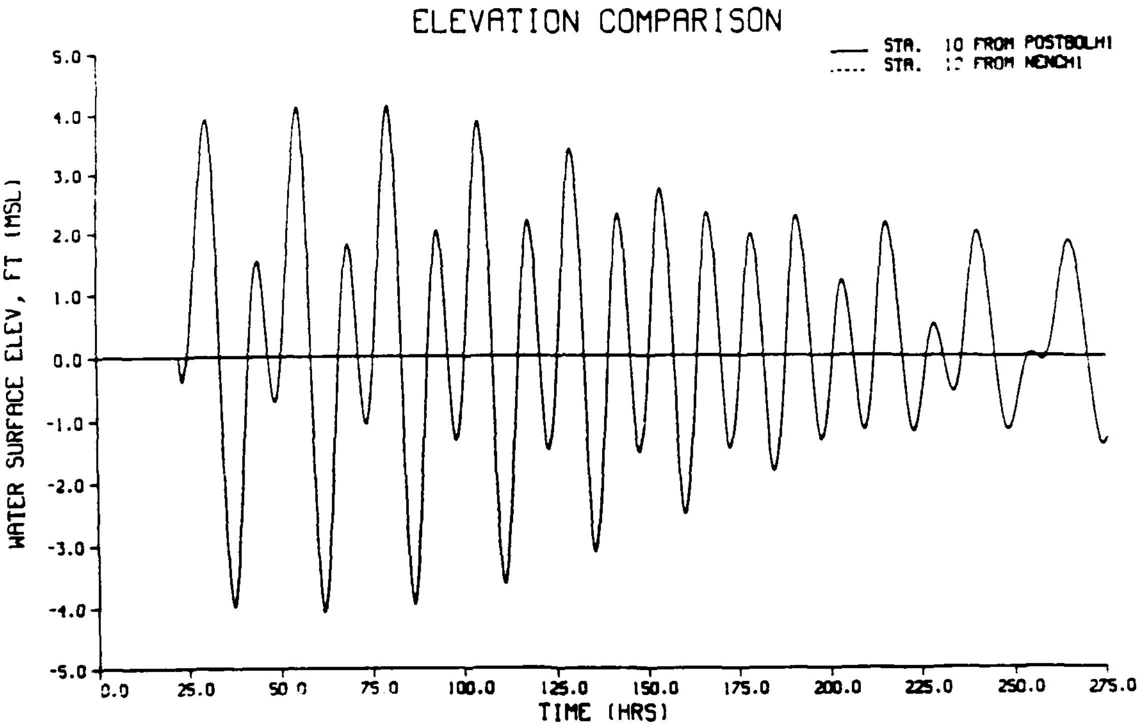


Figure 44. Tidal elevations in Huntington Harbour,
POSTBOL - existing conditions
NENCH1 - navigable entrance channel and navigable connector channel

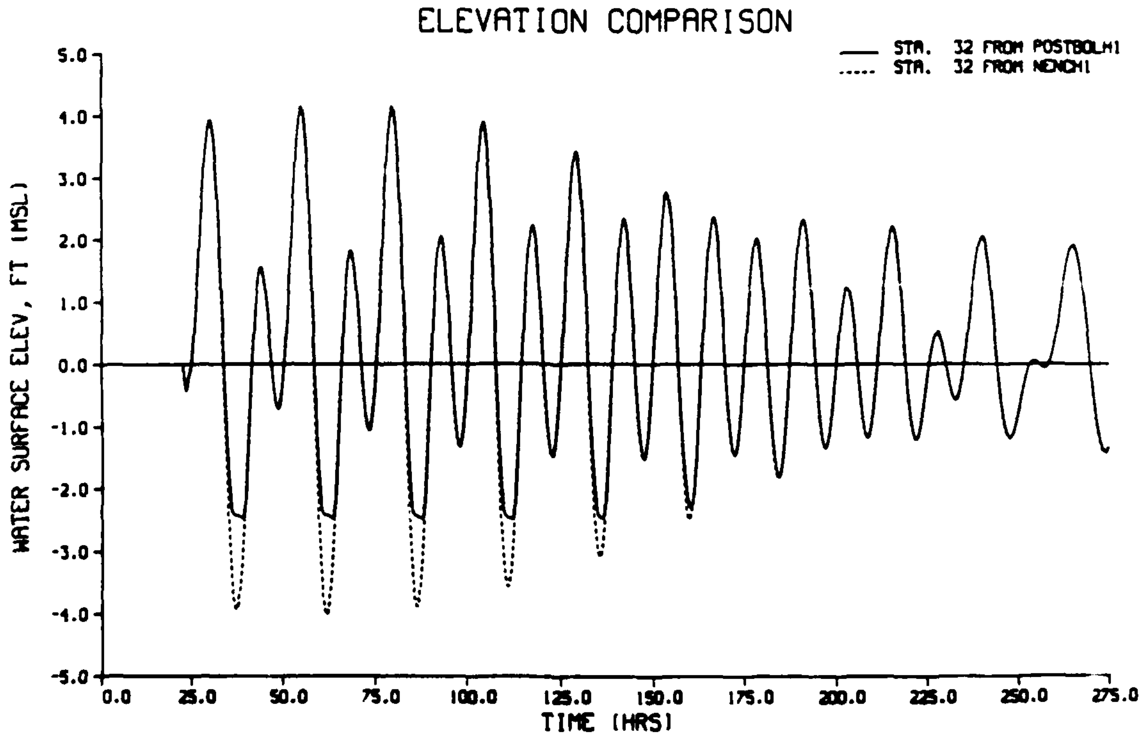


Figure 45. Tidal elevations in Outer Bolsa Bay,
POSTBOL - existing conditions
NENCH1 - navigable entrance channel and navigable connector channel

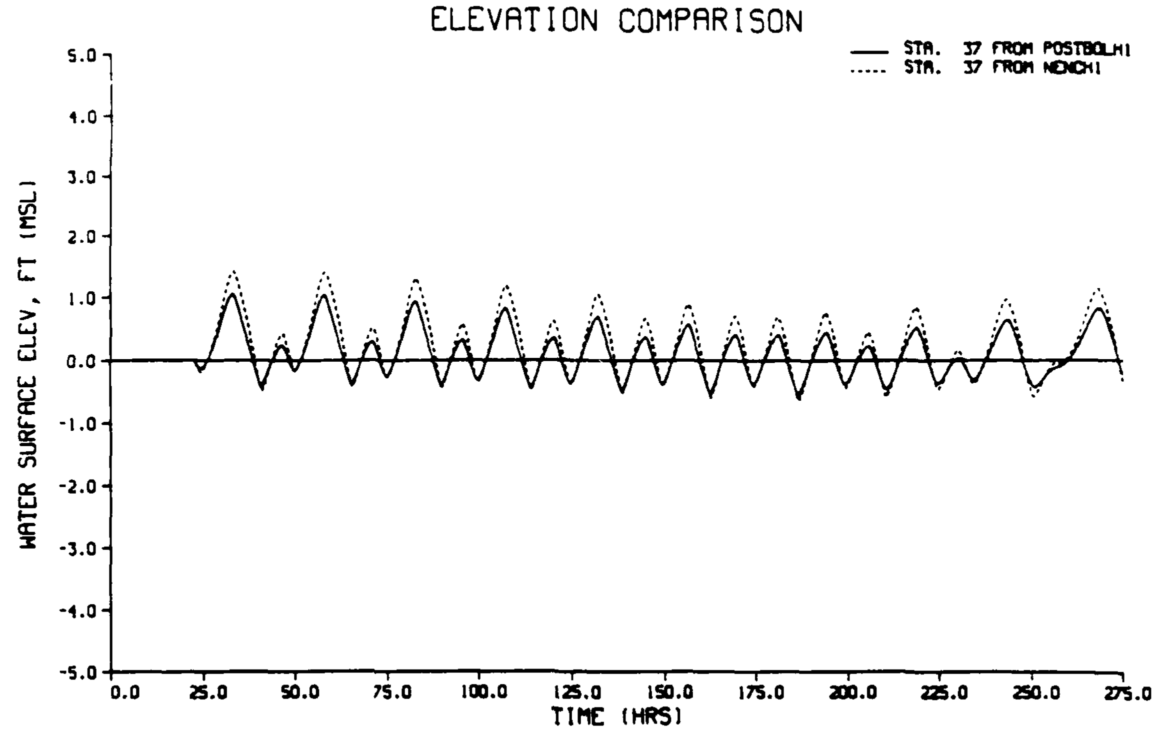


Figure 46. Tidal elevations in Inner Bolsa Bay
POSTBOL - existing conditions
NENCH1 - navigable entrance channel and navigable connector channel

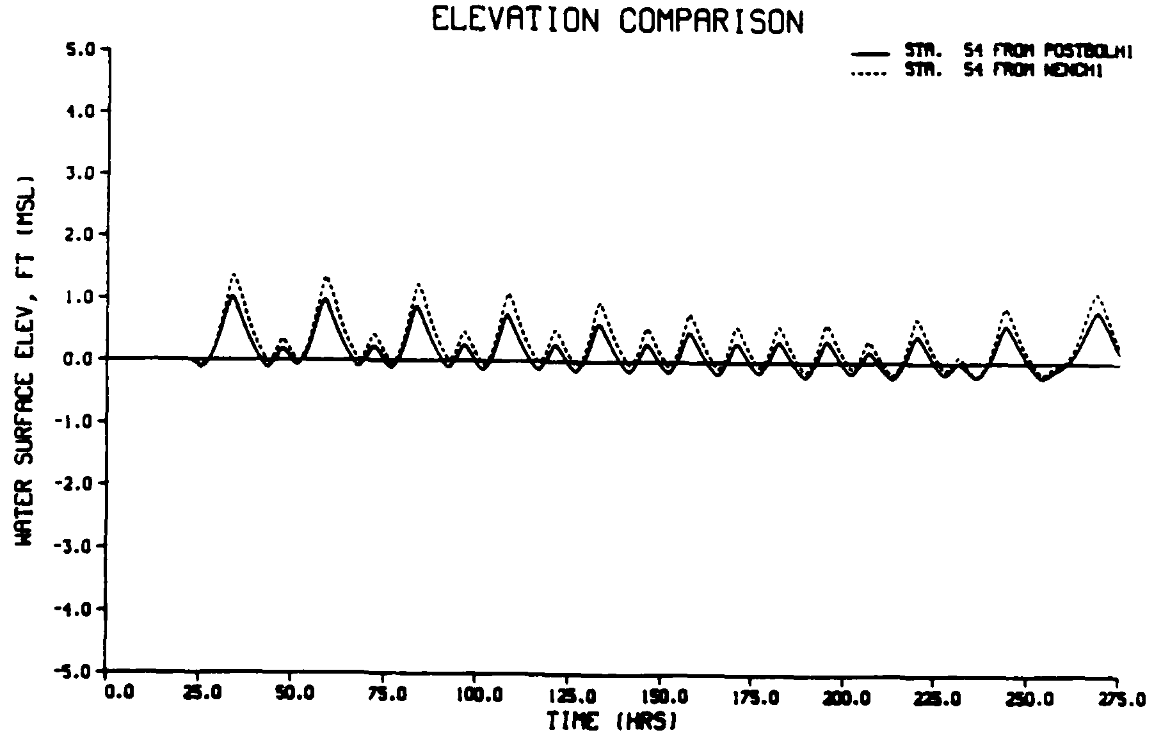


Figure 47. Tidal elevations in DFG muted tidal cell,
POSTBOL - existing conditions
NENCH1 - navigable entrance channel and navigable connector channel

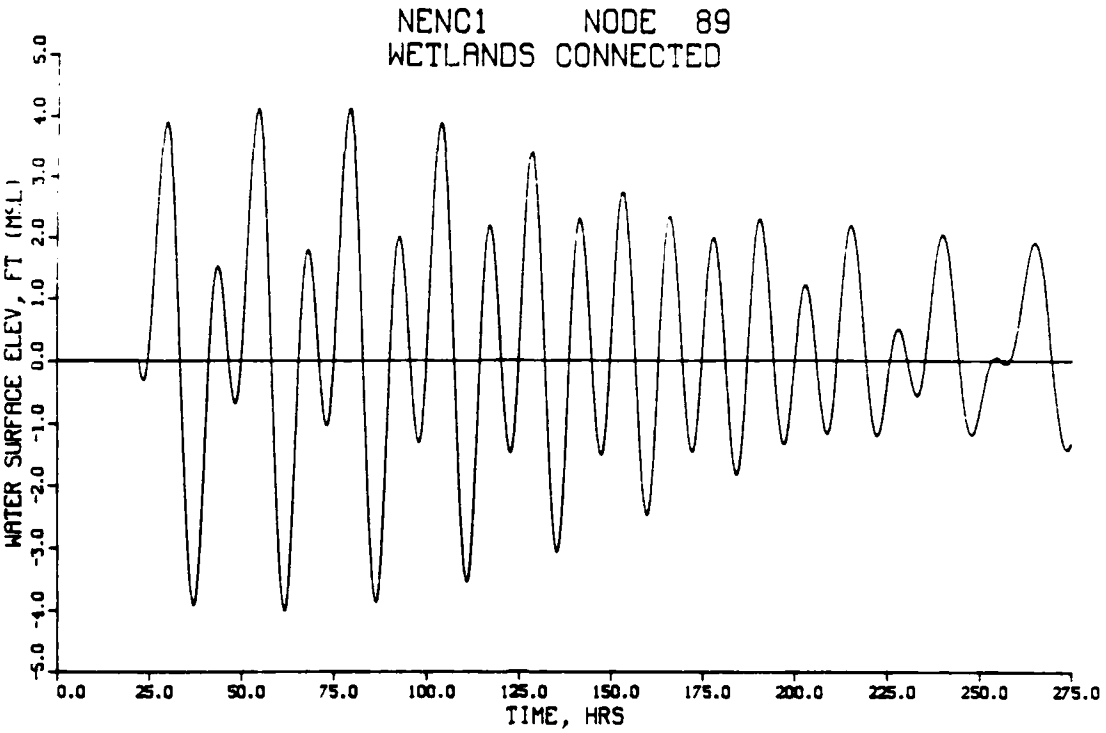


Figure 48. Tidal elevations in proposed marina under navigable entrance channel and navigable connector channel to Huntington Harbour conditions, NENCH1

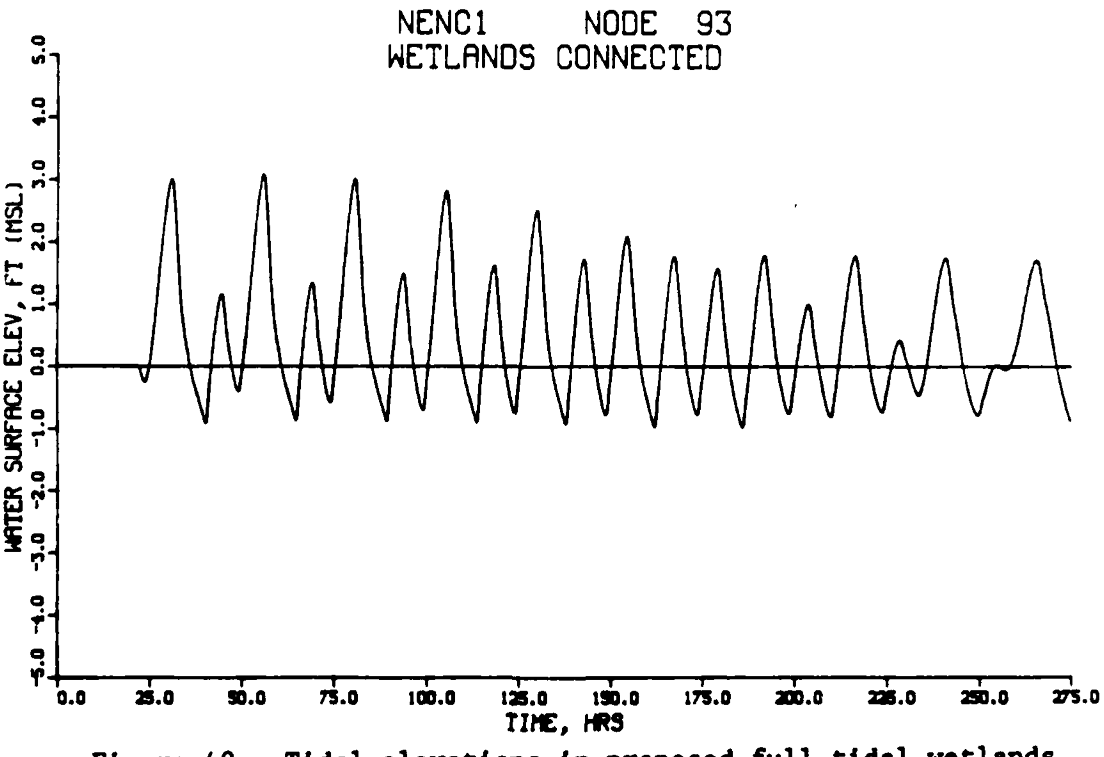


Figure 49. Tidal elevations in proposed full tidal wetlands under navigable entrance channel and navigable connector channel to Huntington Harbour conditions, NENCH1

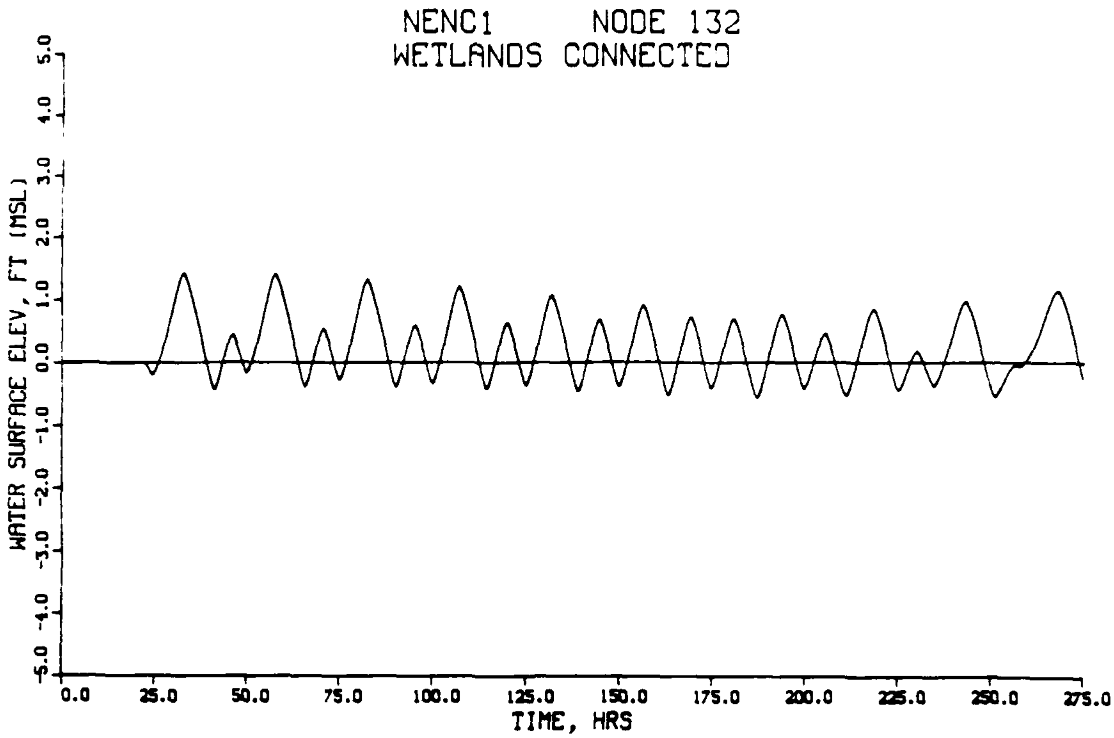
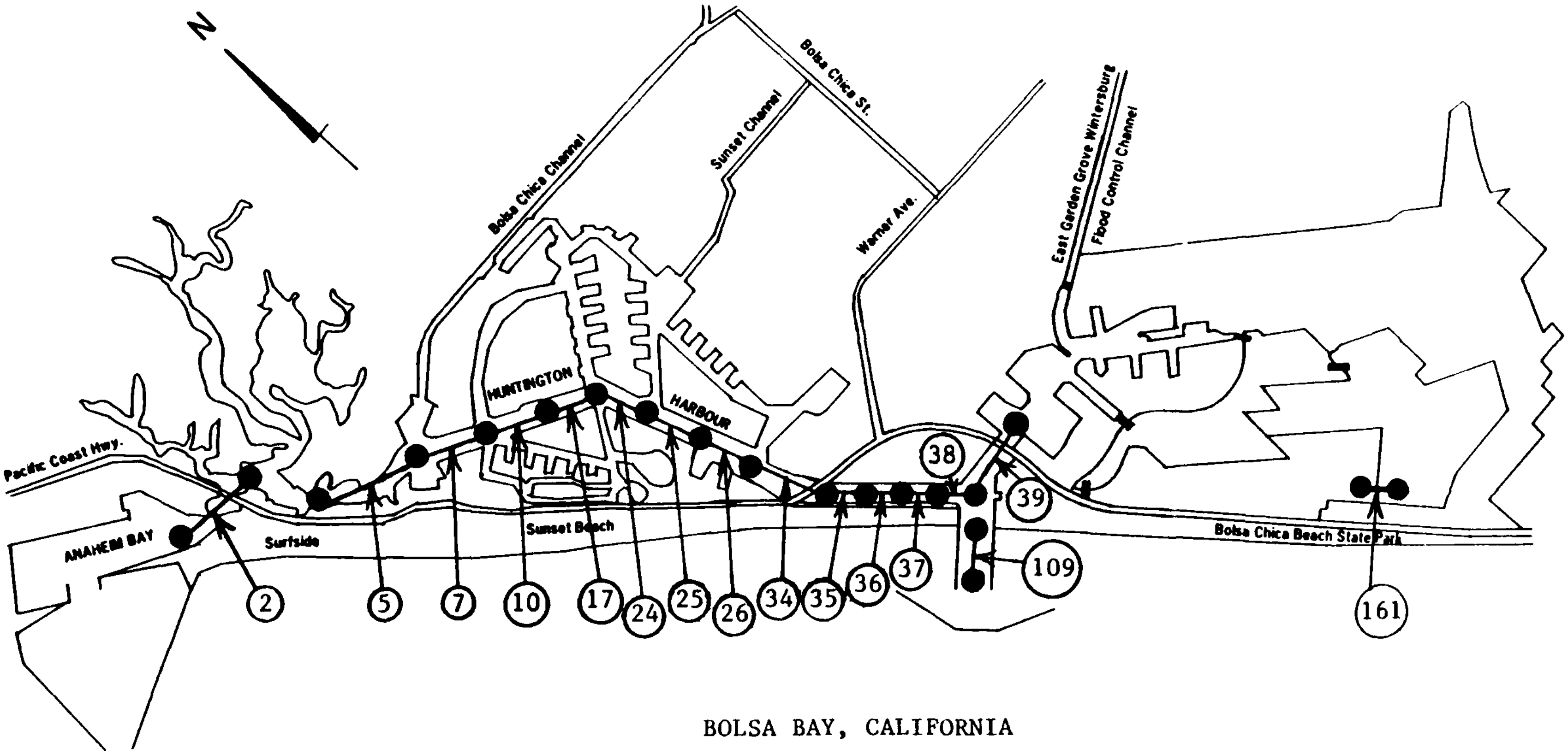


Figure 50. Tidal elevations in proposed muted tidal wetlands under navigable entrance channel and navigable connector channel to Huntington Harbour conditions, NENCH1

Velocities

127. Tidal fluctuations are highly important in the wetland regions. Velocities are relatively unimportant as they will always be low when compared with entrance channel values. Velocities through Huntington Harbour, however, carry implications regarding flushing, water age, and turn-over. Velocity estimates from links of interest are presented in Appendix D. The effect of the NENC1 concept on typically representative average channel velocity time-histories are presented in Figures 52 through 57 for example displays in Huntington Harbour (Links 7, 17, and 26), at relocated Warner Avenue bridge (Link 34), and in Outer Bolsa Bay (Links 36 and 38), respectively.

128. The proposed navigable entrance channel with a navigable connector channel to Huntington Harbour allows a significant portion of the tidal prism of the harbor to enter and exit through the new entrance channel at Bolsa Bay. This flow meets water being transported through Anaheim Bay, and a region of decreased average velocities is created in Huntington Harbour. The hydrodynamic simulation model DYNTRAN computes an average value of velocity which



BOLSA BAY, CALIFORNIA

NENC

Figure 51. Location of links for displaying average channel velocities under navigable entrance channel and navigable connector channel to Huntington Harbour conditions

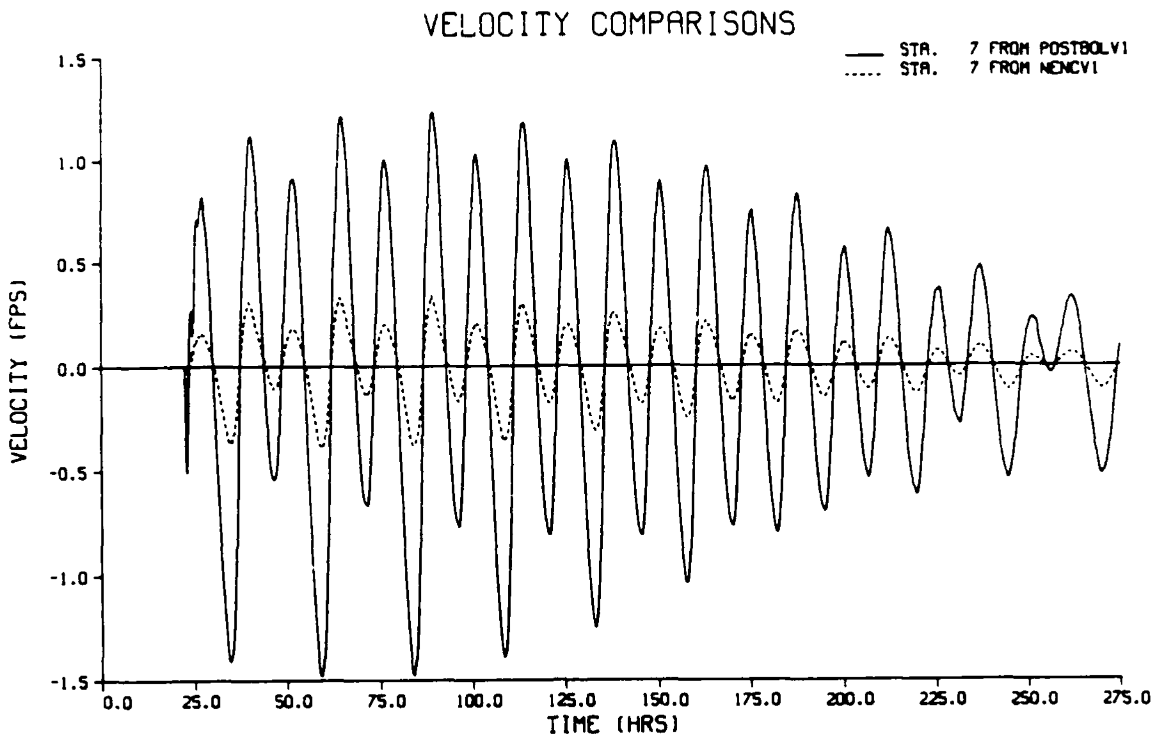


Figure 52. Average channel velocities in Huntington Harbour,
POSTBOL - existing conditions
NENCV1 - navigable entrance channel and navigable connector channel

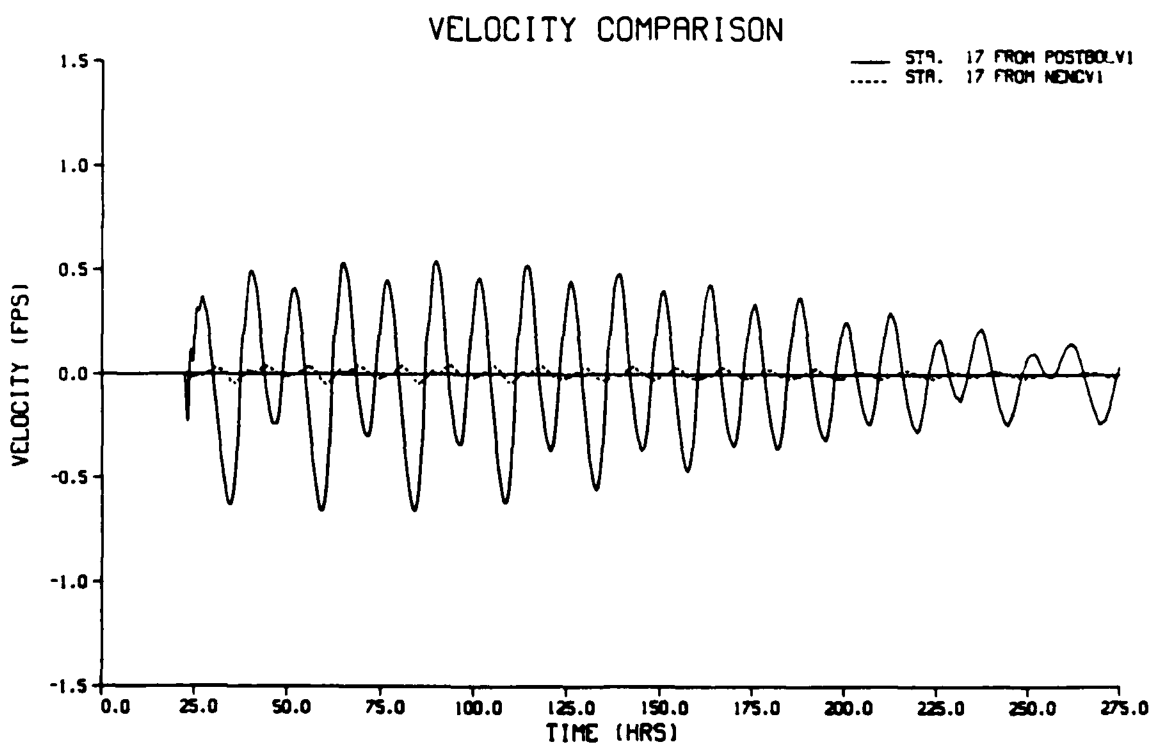


Figure 53. Average channel velocities in Huntington Harbour,
POSTBOL - existing conditions
NENCV1 - navigable entrance channel and navigable connector channel

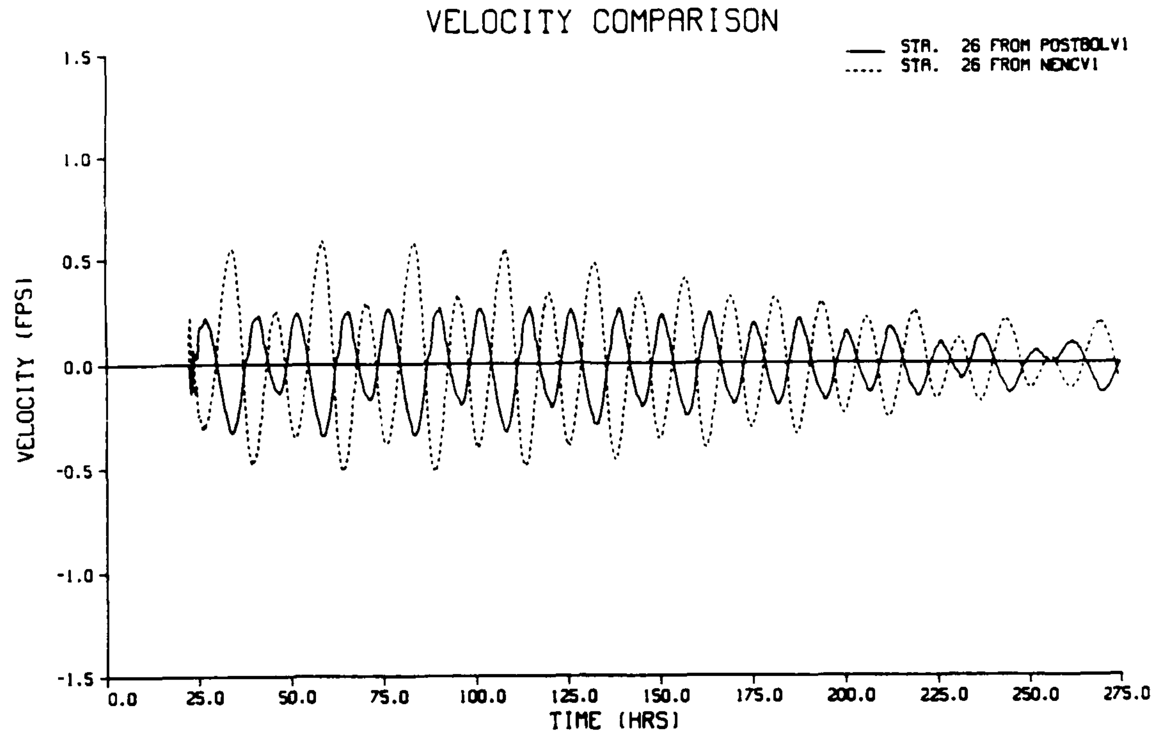


Figure 54. Average channel velocities in Huntington Harbour,
POSTBOL - existing conditions
NENCV1 - navigable entrance channel and navigable connector channel

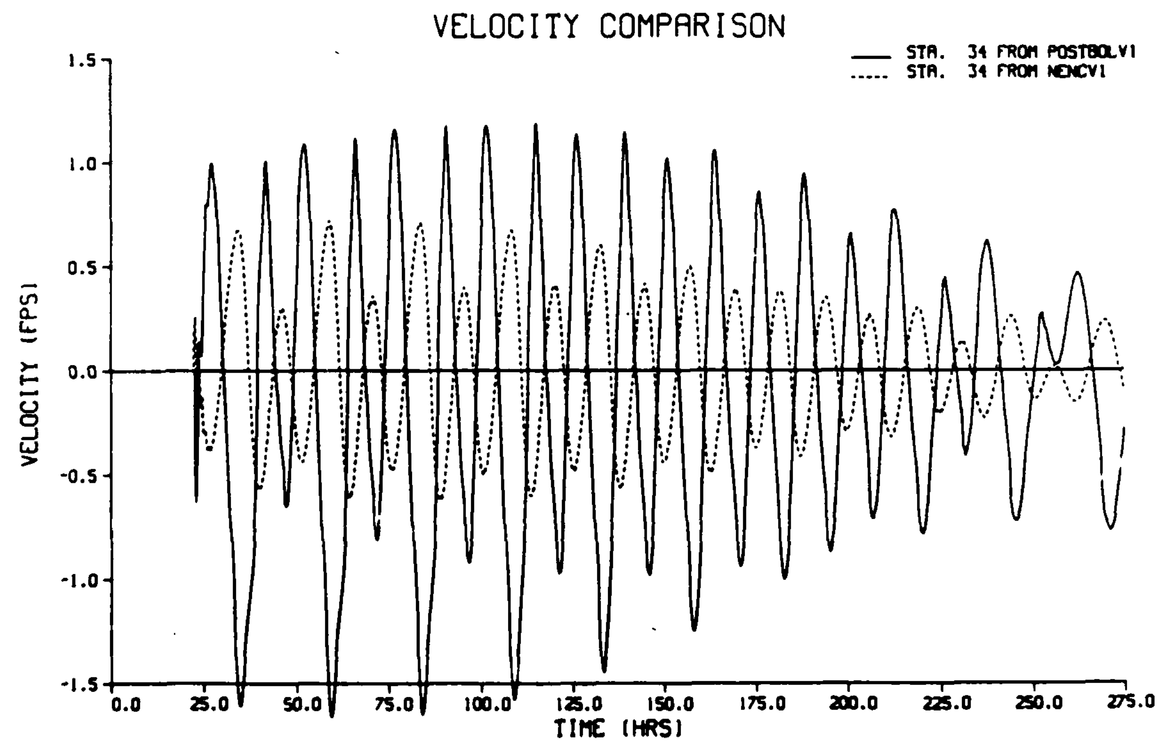


Figure 55. Average channel velocities at Warner Avenue bridge,
POSTBOL - existing conditions
NENCV1 - navigable entrance channel and navigable connector channel

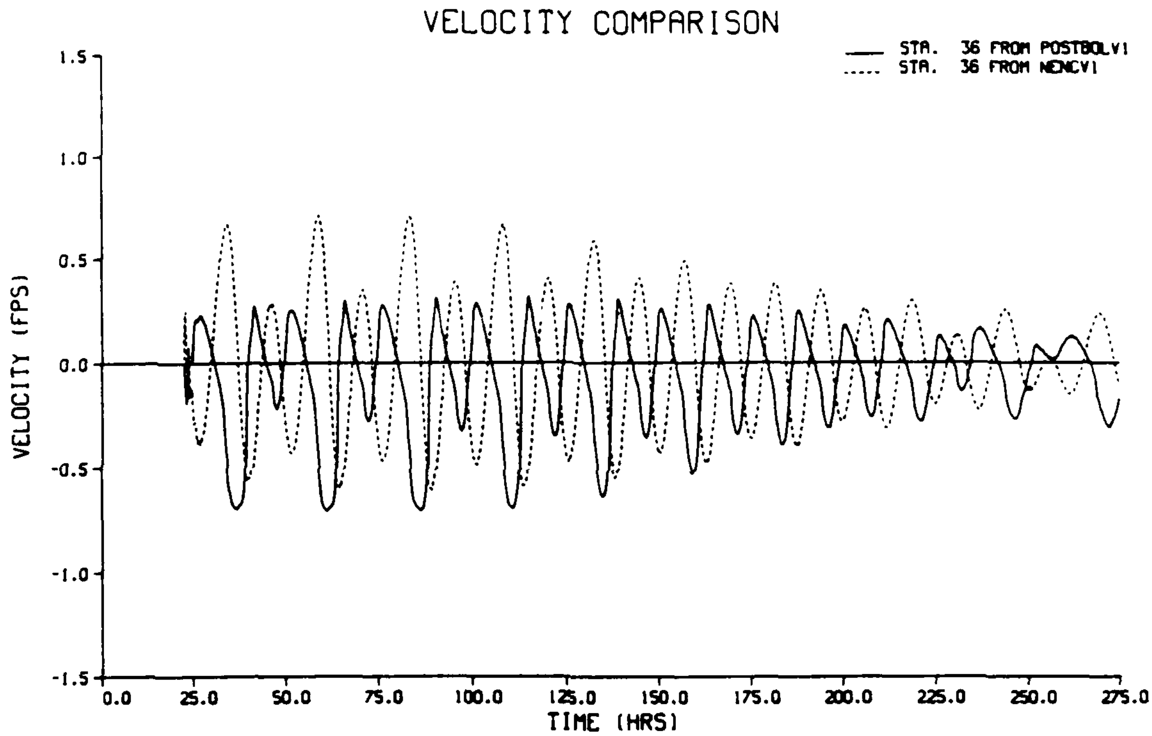


Figure 56. Average channel velocities in Outer Bolsa Bay,
POSTBOL - existing conditions
NENCV1 - navigable entrance channel and navigable connector channel

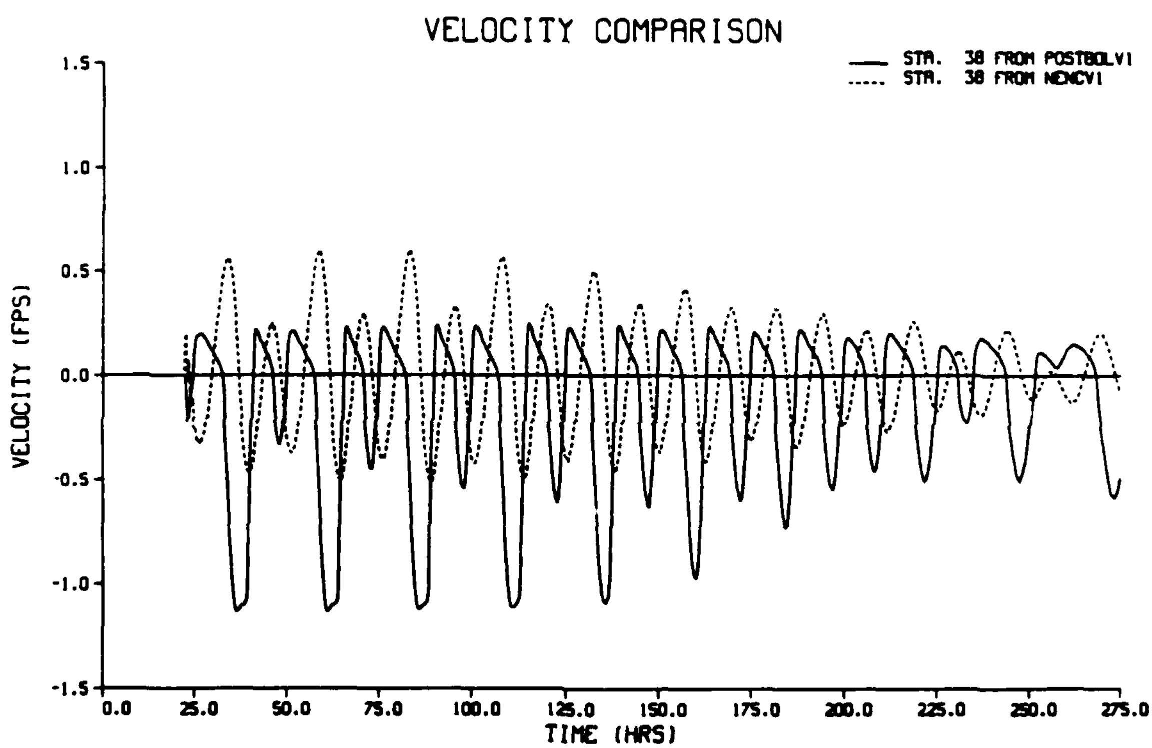


Figure 57. Average channel velocities in Outer Bolsa Bay,
POSTBOL - existing conditions
NENCV1 - navigable entrance channel and navigable connector channel

is determined by dividing the total instantaneous discharge by the total cross-sectional area of the channel. This indeed provides a qualitative indication of the effect of a proposed plan on existing conditions, but other pertinent phenomena exist which significantly affect transport and dispersion of water body constituents.

129. Velocity profiles in the vertical direction at a station on the centerline axis of an open channel indicate regions of velocity greater and lesser than the average value. These velocity gradients at a section preclude the development of a stagnation point in Huntington Harbour. The California coastal sea breeze creates additional circulation within the interconnecting channels of the harbor to further increase transport through the region. If the ocean tides were truly periodic, if there were no wind condition effects, and if the velocity of flow in an open channel was uniform over the entire cross-section, it might be possible for a stagnation region to become established in a harbor. However, the tide amplitude changes substantially with each cycle and, since the effects of bottom friction are non-linear, it is virtually impossible to have a stationary line of stagnation in a real world situation.

130. Maximum average channel velocities resulting from the NENC1 concept for all links along the main Huntington Harbour channel and Outer Bolsa Bay are compared with existing condition velocities in Table 5.

Effect of wetlands connection

131. Existing Inner Bolsa Bay may or may not be connected to the proposed muted tidal wetland enhancement by an opening through the dike along Link 161 which would connect Node 50 (at the rear of Inner Bolsa Bay) with Node 134 (in the proposed muted tidal wetland region). The DYNTRAN simulations were performed both with and without this wetland connection. It was determined that any effects created by such connections within the wetlands would not propagate through the culvert and tide gate system into the marinas and other regions of Bolsa Bay. Effects within the wetlands are confined to the wetlands. Similarly, alterations in the outer regions do not propagate through the culverts and into the wetlands. Effects of a wetland connection at Link 161 are displayed in Figures 58 through 65 for representative locations in the area, and are seen to be imperceptible for the navigable entrance with a navigable connector channel to Huntington Harbour concept.

Table 5

POSTBOL, Existing Condition
versus
NENC1, Navigable Entrance Channel
and Navigable Connector Channel to Huntington Harbour

Wetlands Connected

Maximum Average Channel Velocities Along Main Channel System

Location	Link No	Maximum Average Channel Velocity ft per sec	
		POSTBOL	NENC1
Pacific Coast Highway bridge	2	2.78	1.41
Huntington Harbour	5	1.42	0.49
Huntington Harbour	7	1.48	0.39
Huntington Harbour	10	0.71	0.09
Huntington Harbour	17	0.66	0.05
Huntington Harbour	24	0.57	0.27
Huntington Harbour	25	0.30	0.35
Huntington Harbour	26	0.34	0.59
Warner Avenue bridge	34	1.65	0.72
Outer Bolsa Bay	35	1.35	0.67
Outer Bolsa Bay	36	0.71	0.71
Outer Bolsa Bay	37	0.88	0.75
Outer Bolsa Bay	38	1.12	0.60
Entrance channel to marina	109	----	0.44

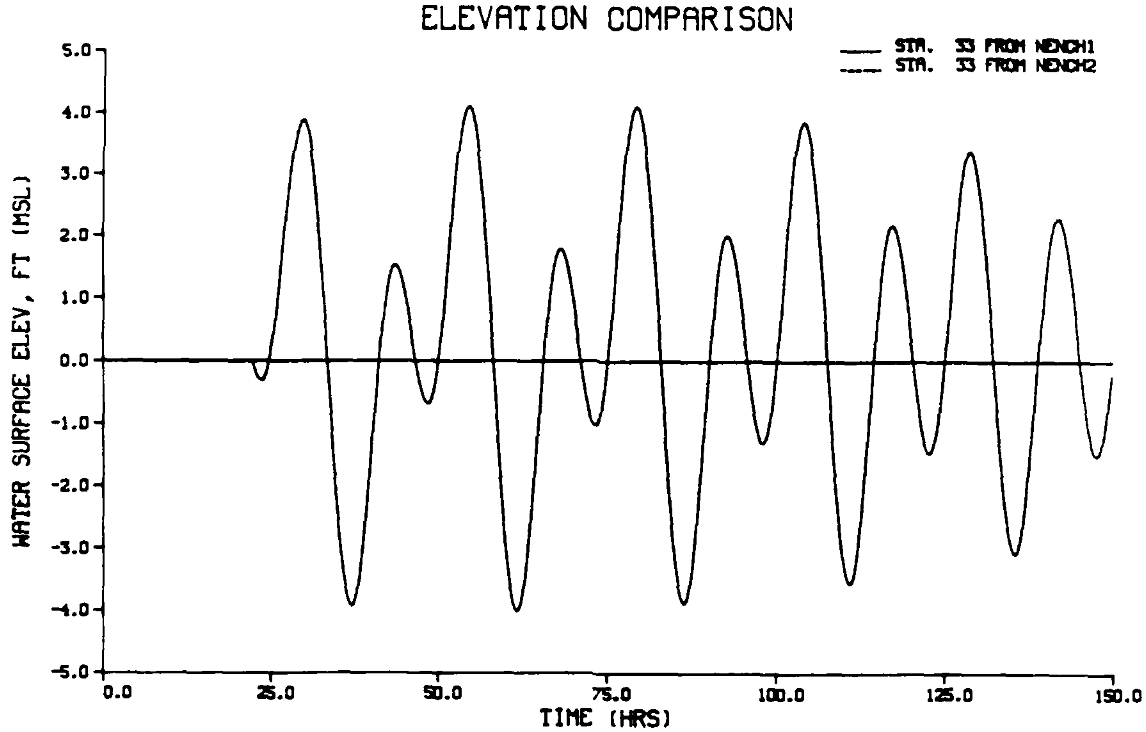


Figure 58. Effect of wetlands connection on tidal elevations, Outer Bolsa Bay, navigable entrance channel and navigable connector channel, NENCH1 - wetlands connected, NENCH2 - wetlands not connected

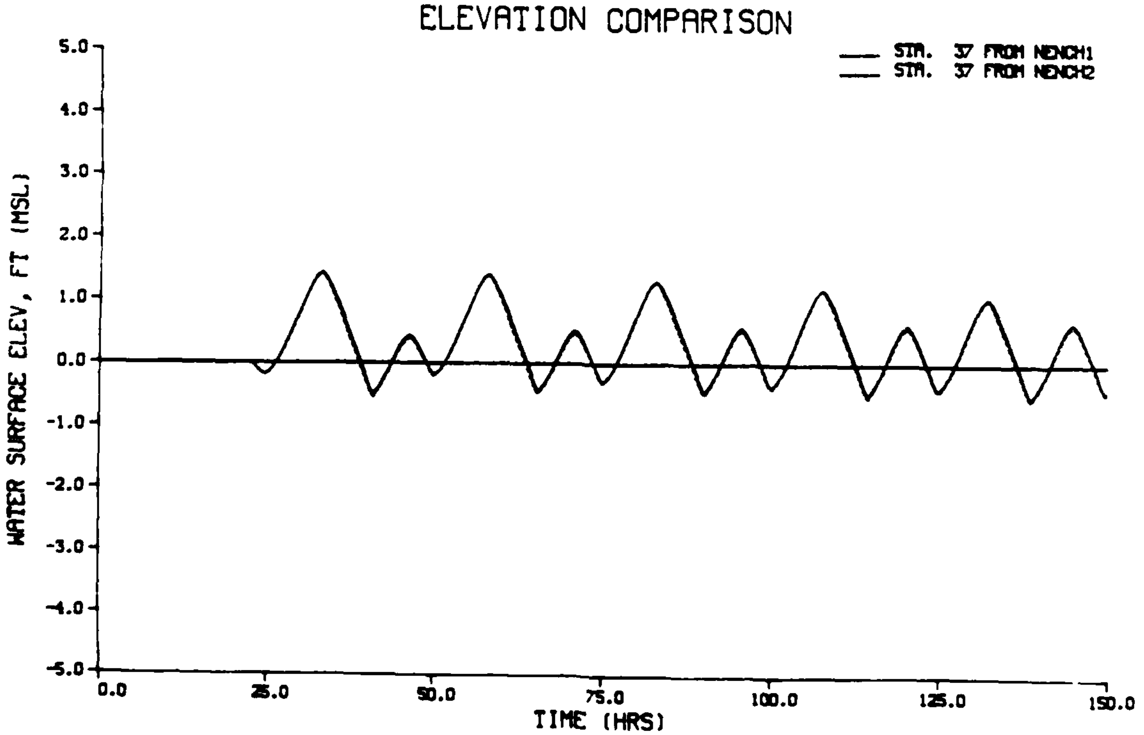


Figure 59. Effect of wetlands connection on tidal elevations, Inner Bolsa Bay, navigable entrance channel and navigable connector channel, NENCH1 - wetlands connected, NENCH2 - wetlands not connected

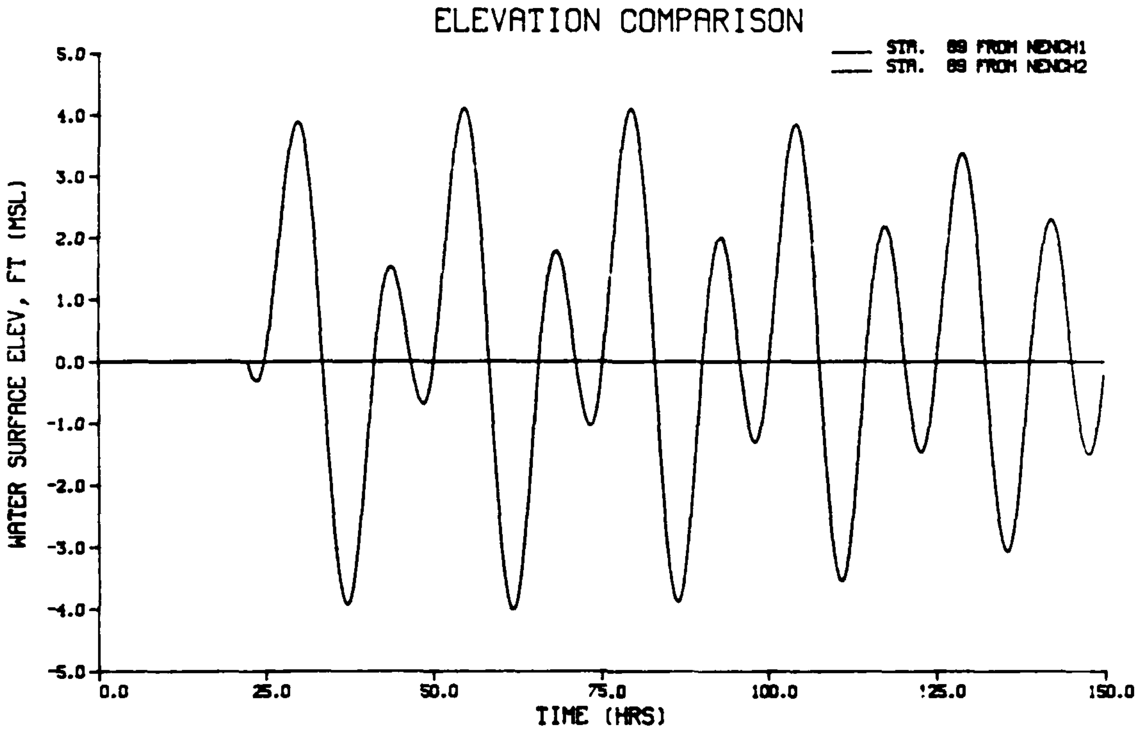


Figure 60. Effect of wetlands connection on tidal elevations, proposed marina, navigable entrance channel and navigable connector channel, NENCH1 - wetlands connected, NENCH2 - wetlands not connected

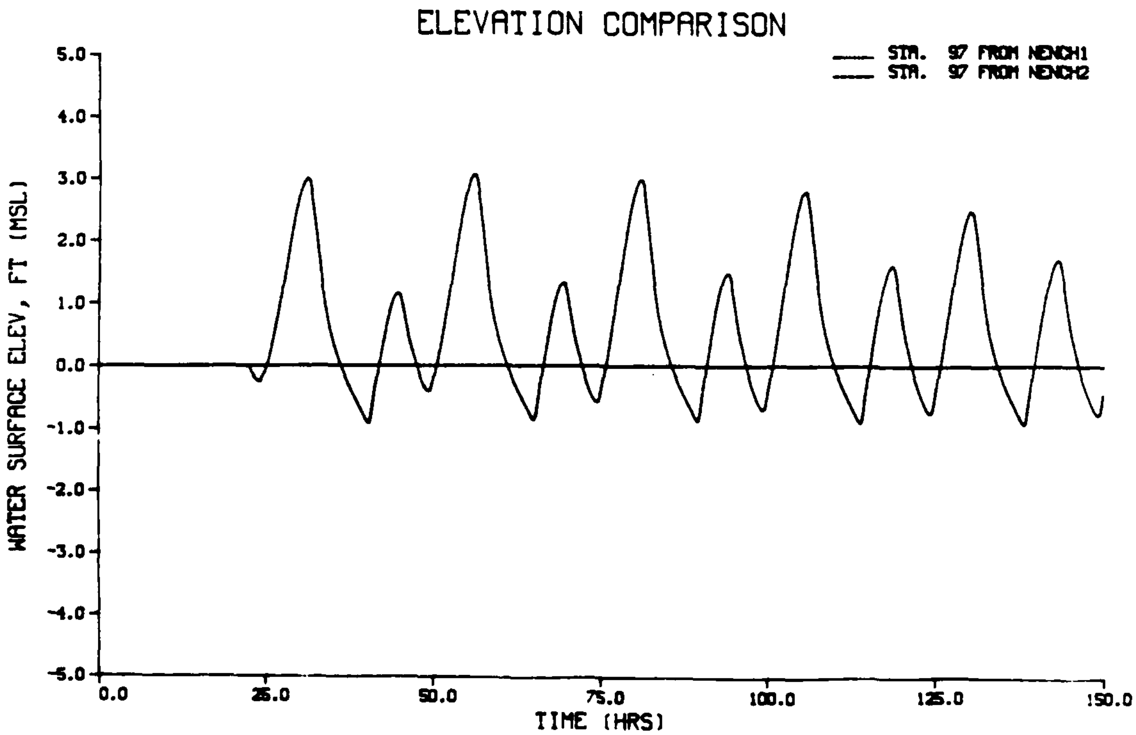


Figure 61. Effect of wetlands connection on tidal elevations, proposed full tidal wetlands, navigable entrance and connector channel, NENCH1 - wetlands connected, NENCH2 - wetlands not connected

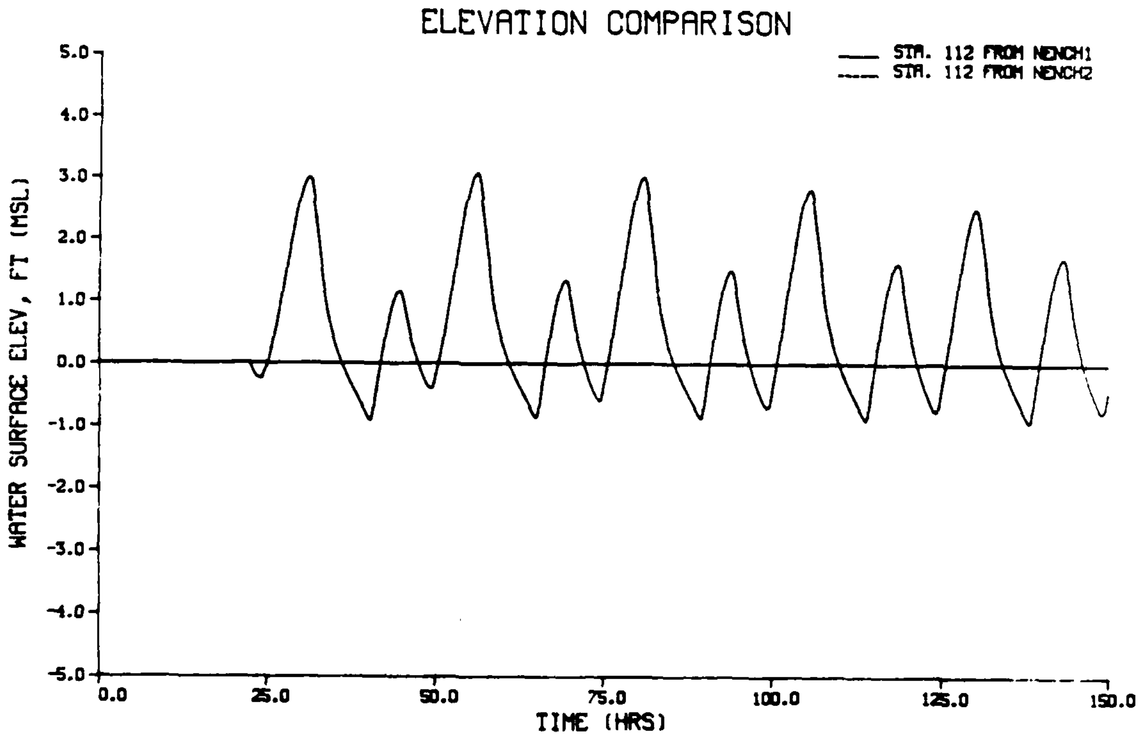


Figure 62. Effect of wetlands connection on tidal elevations, proposed full tidal wetlands, navigable entrance and connector channel, NENCH1 - wetlands connected, NENCH2 - wetlands not connected

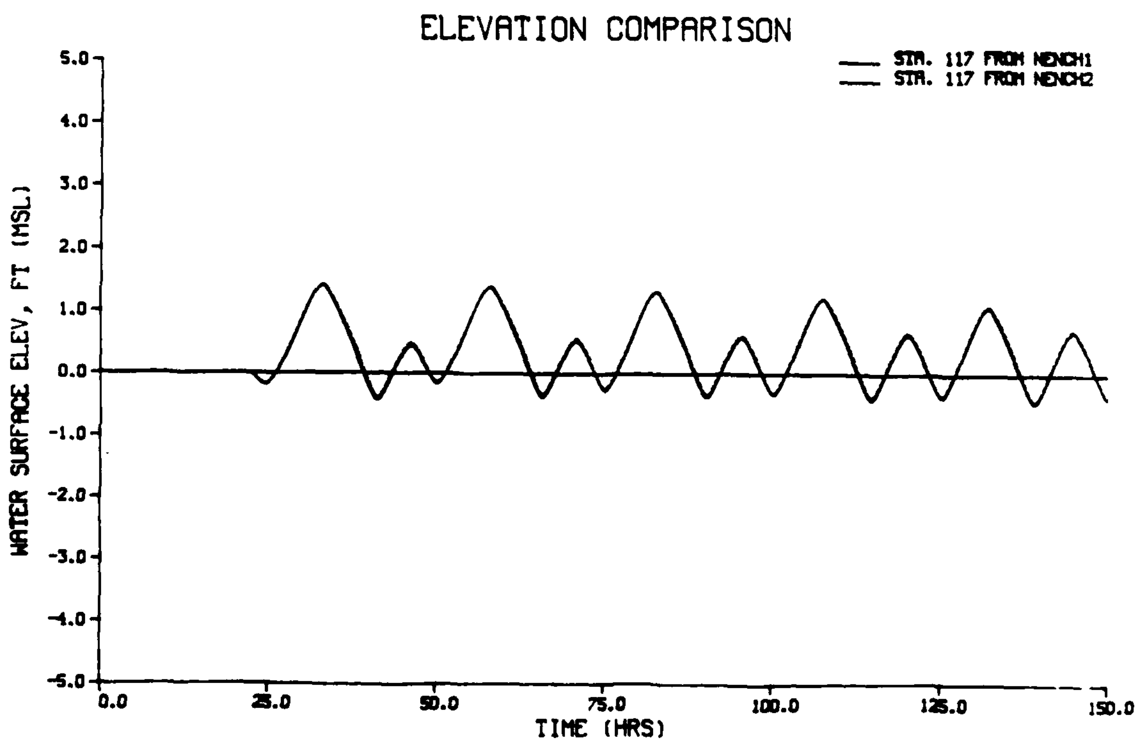


Figure 63. Effect of wetlands connection on tidal elevations, proposed muted tidal wetlands, navigable entrance and connector channel, NENCH1 - wetlands connected, NENCH2 - wetlands not connected

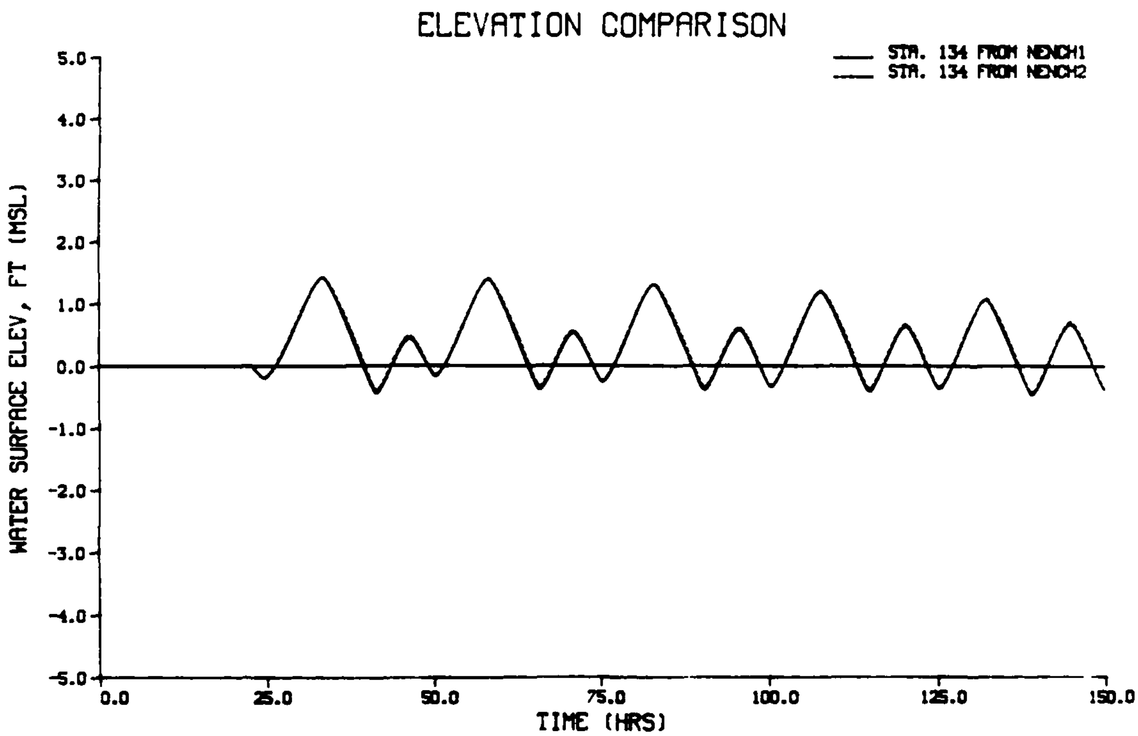


Figure 64. Effect of wetlands connection on tidal elevations, proposed muted tidal wetlands, navigable entrance and connector channel, NENCH1 - wetlands connected, NENCH2 - wetlands not connected

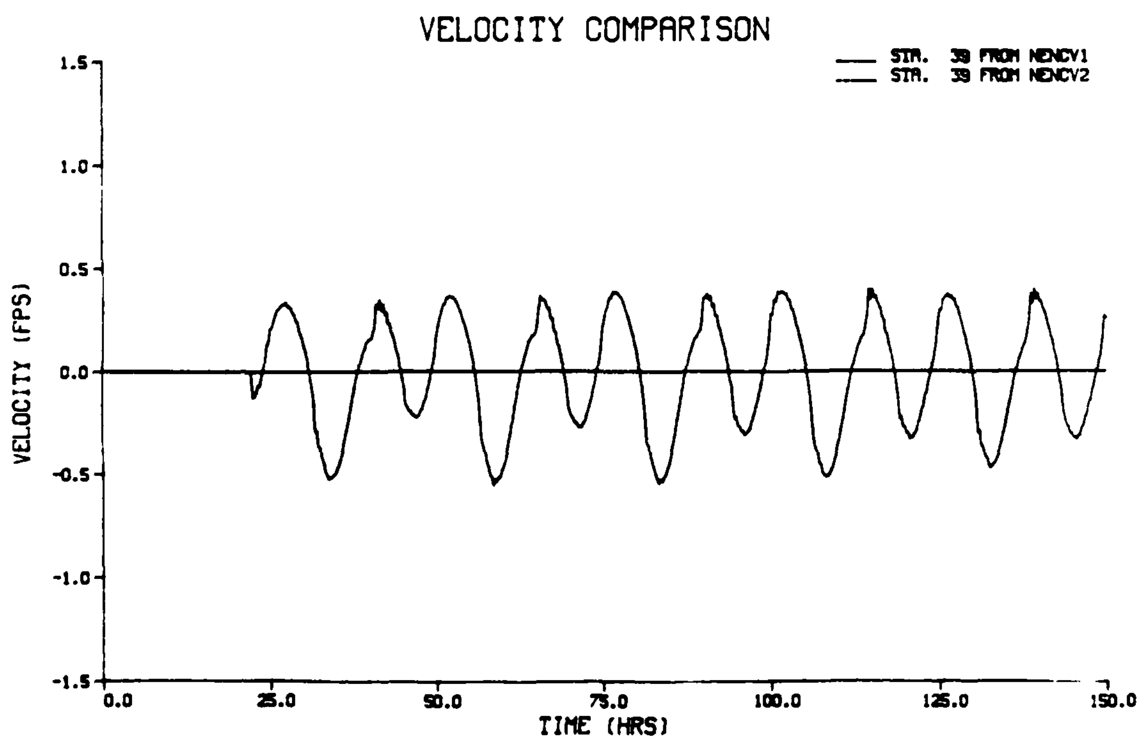


Figure 65. Effect of wetlands connection on average channel velocities, proposed marina channel, navigable entrance and connector channel, NENCH1 - wetlands connected, NENCH2 - wetlands not connected

NENNC
Navigable Entrance Channel
and Non-Navigable Connector Channel to Huntington Harbour

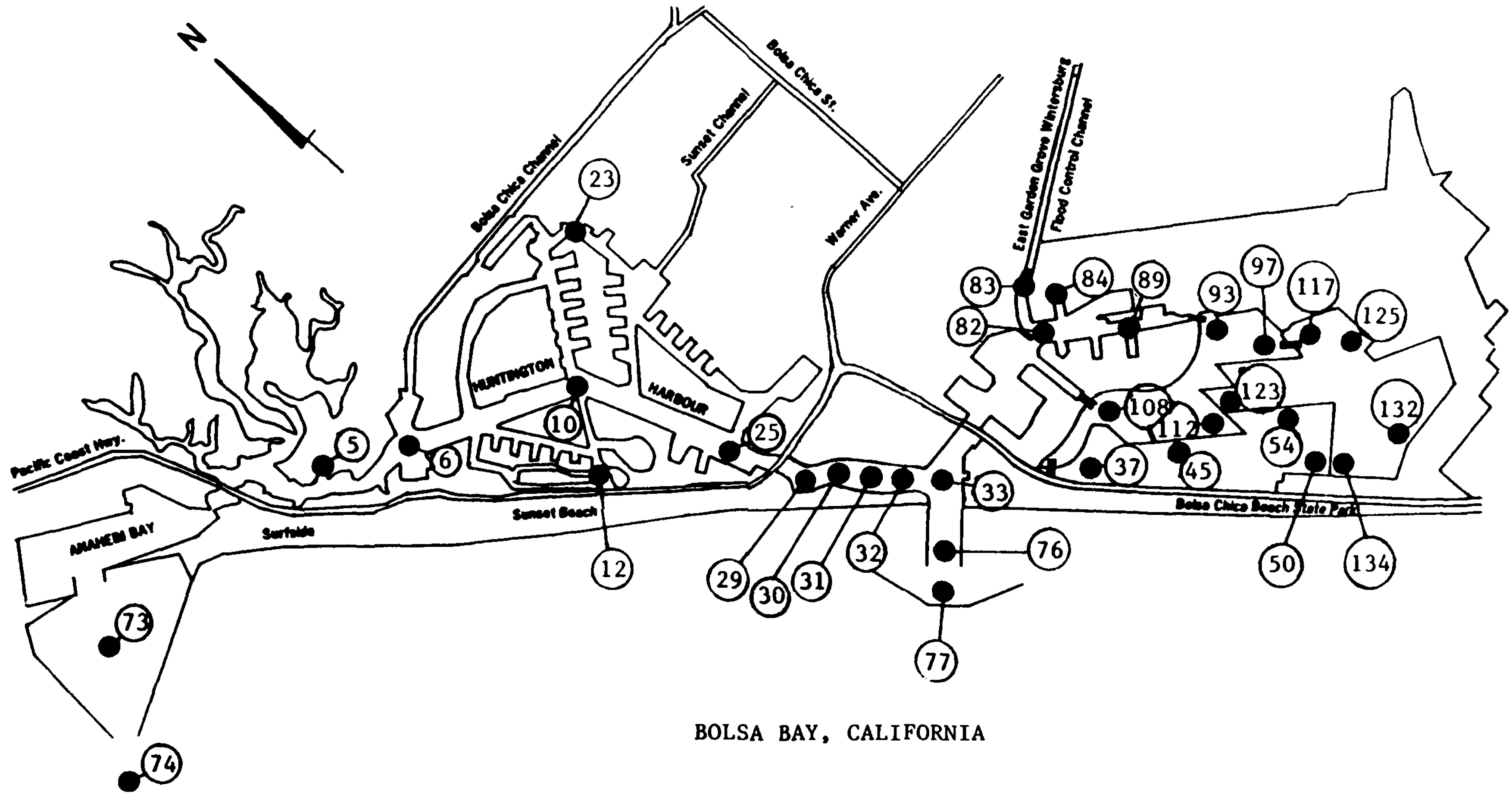
Entrance channel characteristics

132. A variation of the navigable entrance channel concept (the Preferred Alternative) considers that Outer Bolsa Bay will remain in its present condition, and that no navigable connector channel to Huntington Harbour from the proposed new entrance will be constructed. All small craft which utilize Huntington Harbour will continue to enter and exit through Anaheim Bay. Similarly, all water craft utilizing the proposed new marina will enter and leave by way of the new entrance. Because no pleasure craft from Huntington Harbour will be using the new entrance, that entrance channel need not be as wide as previously considered. Accordingly, the entrance channel has been designed under these considerations to accommodate a smaller number of vessels, and was determined to require a bottom width of 500 ft at an elevation of -23 ft msl. All other characteristics of the entrance channel and marina plan remain unchanged from the navigable entrance with a navigable connector channel to Huntington Harbour concept.

Tidal elevations

133. The most recent hydrographic survey of Outer Bolsa Bay indicated that the bay channel has a depth of at least -4.5 ft msl. Field tide measurements, and hydrodynamic simulations of Outer Bolsa Bay under existing conditions, indicated that low tide in Outer Bay falls to only around -2.0 to -2.5 ft msl even under extreme low ocean tides (-4.0 ft msl). Water level is being retained in the Outer Bay by frictional effects and the constriction afforded by the Warner Avenue Bridge, because all flow to the wetlands passes through this section. In the presence of a new entrance channel at Bolsa Bay, Outer Bolsa Bay will respond more nearly as the ocean tide, and the water level at low tide will fall lower than -2.5 ft msl. However, because the channel through Outer Bolsa Bay is deeper than the lowest ocean tide being utilized, Outer Bolsa Bay will not go dry, even at extreme low tide.

134. Results of the hydrodynamic simulations of tidal elevations for significant nodes of interest are presented in Appendix E. Tidal ranges at representative regions throughout the bay system are presented in Table 6.



BOLSA BAY, CALIFORNIA

NENNC

Figure 66. Location of nodes for displaying water surface elevations under navigable entrance channel and non-navigable connector channel to Huntington Harbour conditions

Table 6

NENNC1
Navigable Entrance Channel
and Non-Navigable Connector Channel to Huntington Harbour

Wetlands Connected

Tide Ranges at Representatives Nodes

Location	Node No	High Tide feet, msl	Low Tide feet, msl
Huntington Harbour	10	4.10	-4.09
Outer Bolsa Bay	29	4.10	-4.05
Outer Bolsa Bay	30	4.10	-4.05
Outer Bolsa Bay	31	4.09	-4.05
Outer Bolsa Bay	32	4.09	-4.03
Outer Bolsa Bay	33	4.09	-4.01
Inner Bolsa Bay	37	1.40	-0.43
Inner Bolsa Bay	45	1.40	-0.38
Inner Bolsa Bay	50	1.41	-0.39
DFG muted tidal cell	54	1.34	0.01
Proposed marina	89	4.09	-4.01
Proposed full tidal wetlands	93	3.08	-0.86
Proposed full tidal wetlands	108	3.08	-0.86
Proposed muted tidal wetlands	123	1.41	-0.39
Proposed muted tidal wetlands	132	1.41	-0.38

The effect of the NENNC1 concept on typically representative water surface elevation time-histories are presented in Figures 67 through 70 for Huntington Harbour (Node 10), Outer Bolsa Bay (Node 32), Inner Bolsa Bay (Node 37), and the DFG muted tidal cell (Node 54), respectively. Time-histories of water surface elevations for the proposed marina (Node 89), proposed full tidal wetland areas (Node 93), and proposed muted tidal wetland areas (Node 132), are shown in Figures 71 through 73, respectively.

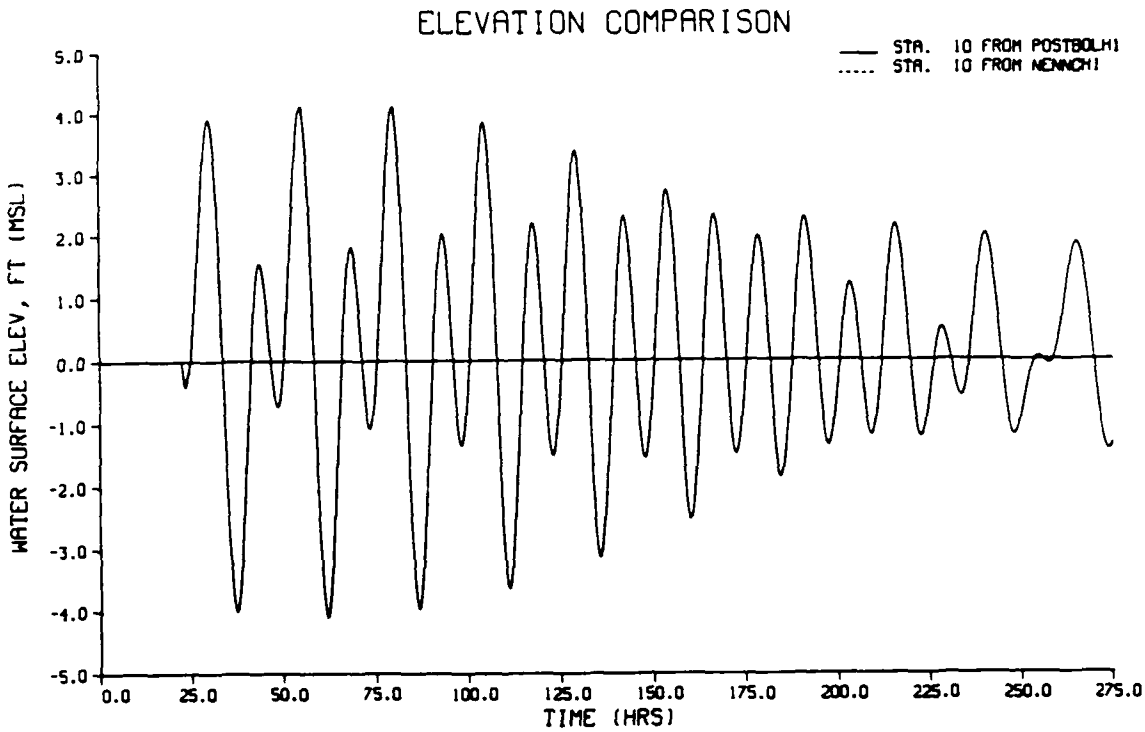


Figure 67. Tidal elevations in Huntington Harbour,
POSTBOL - existing condition
NENNCH1 - navigable entrance channel and non-navigable connector channel

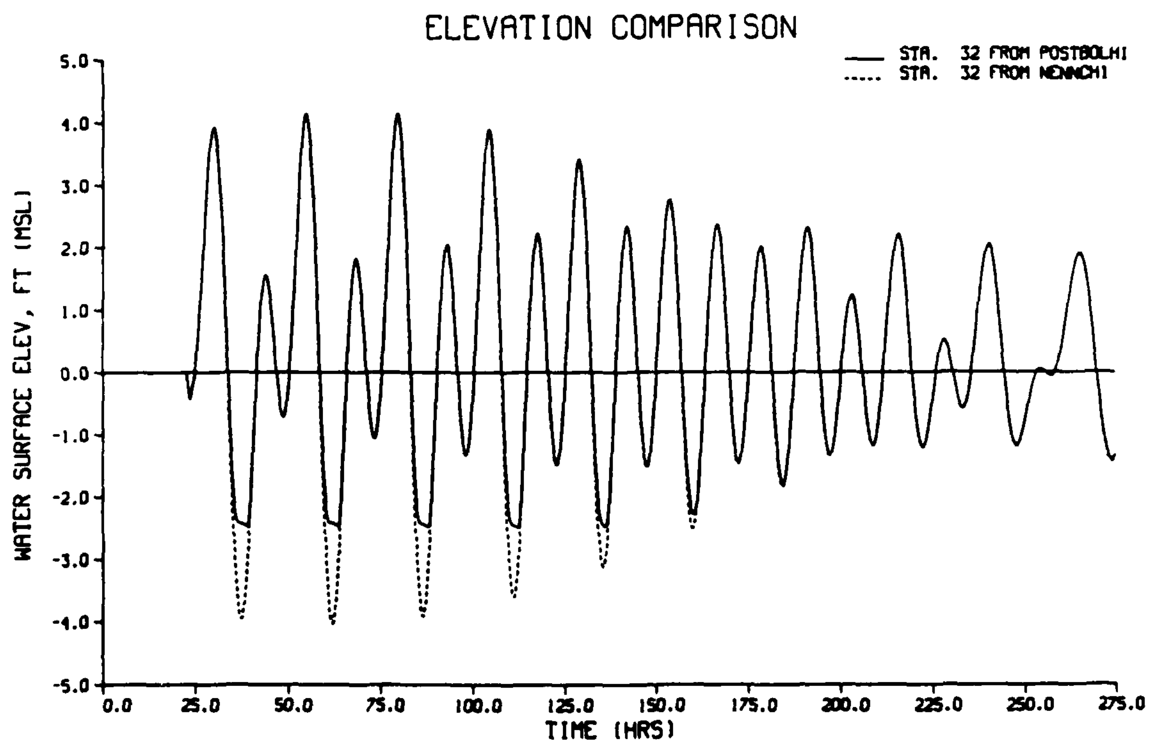


Figure 68. Tidal elevations in Outer Bolsa Bay,
POSTBOL - existing condition
NENNCH1 - navigable entrance channel and non-navigable connector channel

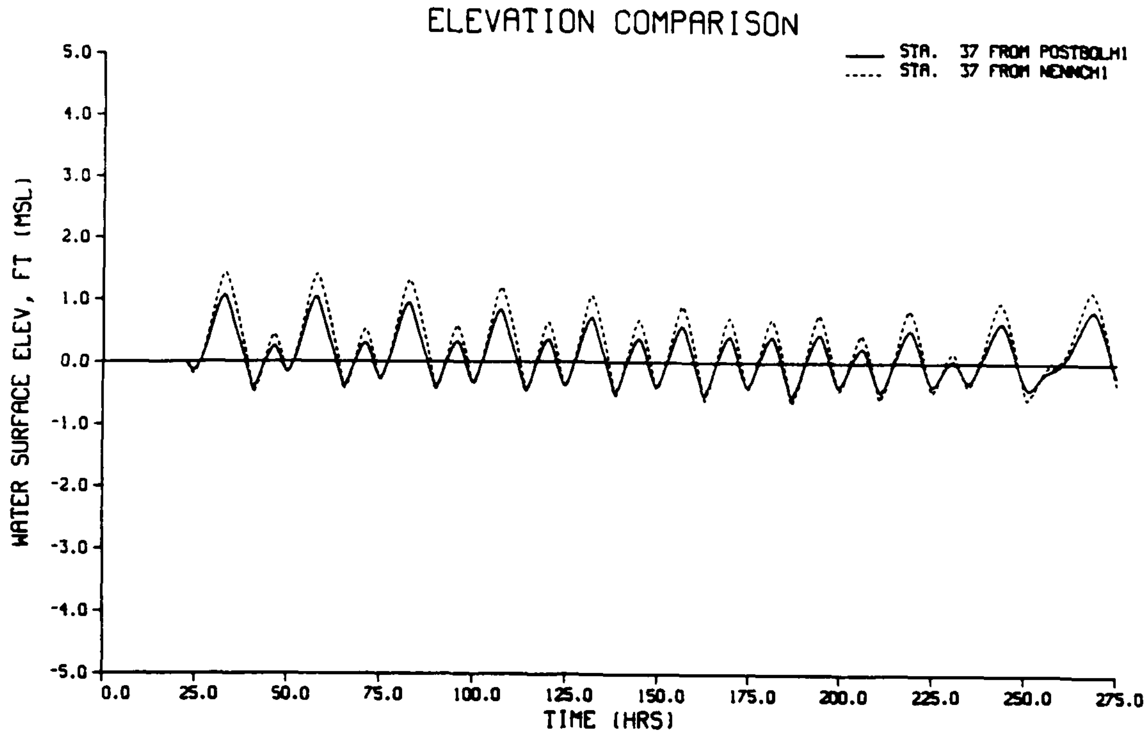


Figure 69. Tidal elevations in Inner Bolsa Bay,
POSTBOL - existing condition
NENNCH1 - navigable entrance channel and non-navigable connector channel

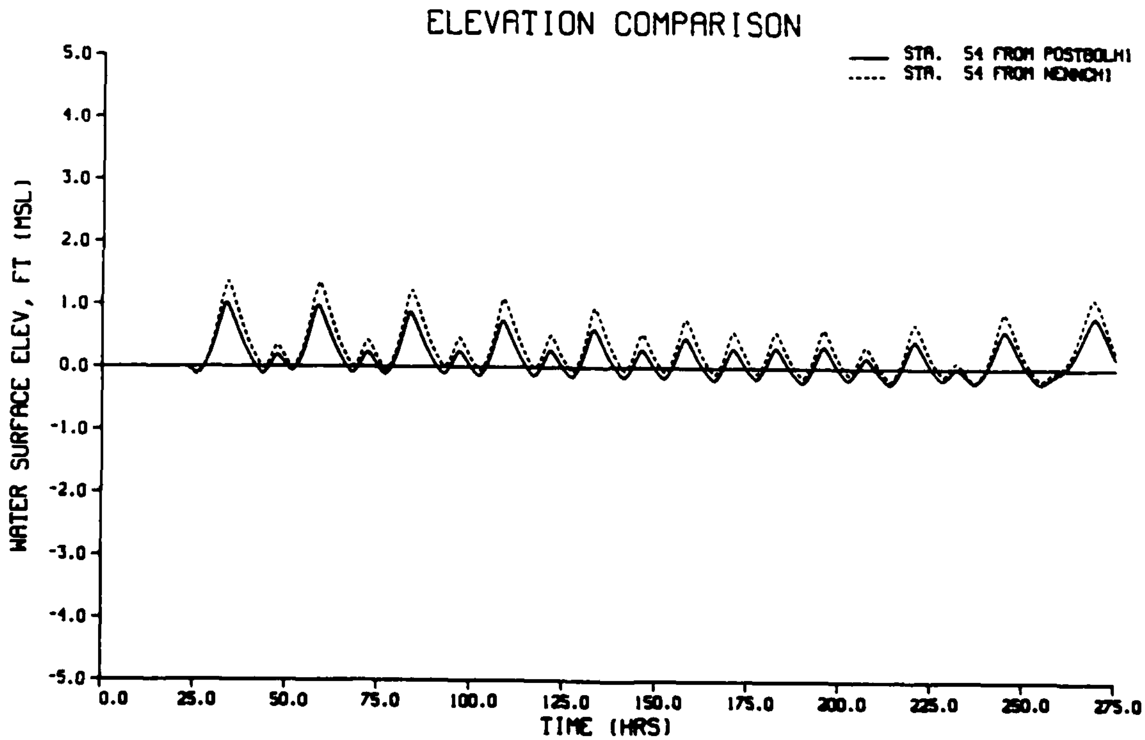


Figure 70. Tidal elevations in DFG muted tidal cell,
POSTBOL - existing condition
NENNCH1 - navigable entrance channel and non-navigable connector channel

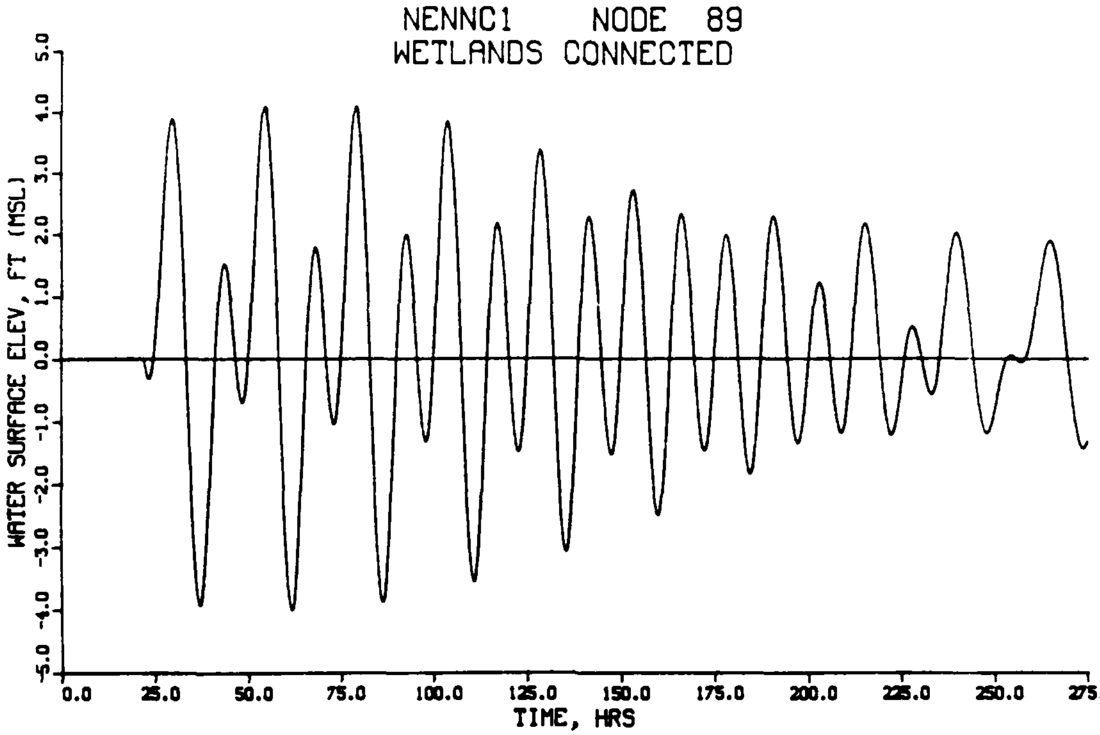


Figure 71. Tidal elevations in proposed marina under navigable entrance channel and non-navigable connector channel to Huntington Harbour conditions, NENNCH1

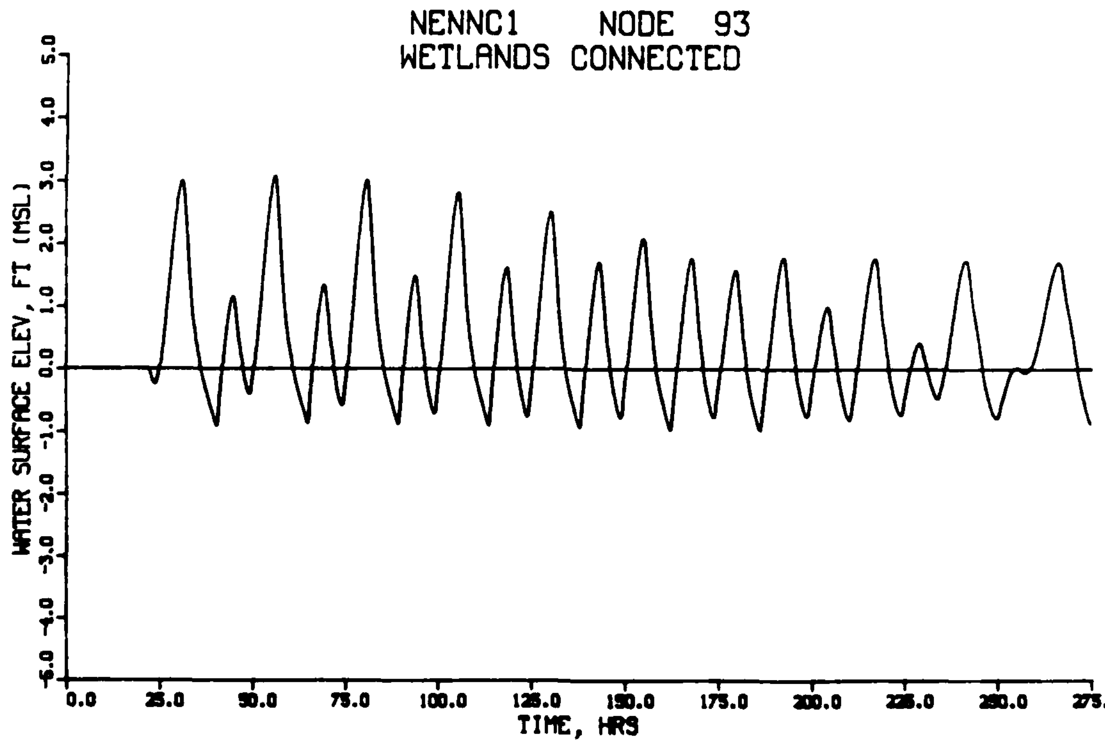


Figure 72. Tidal elevations in proposed full tidal wetlands under navigable entrance channel and non-navigable connector channel to Huntington Harbour conditions, NENNCH1

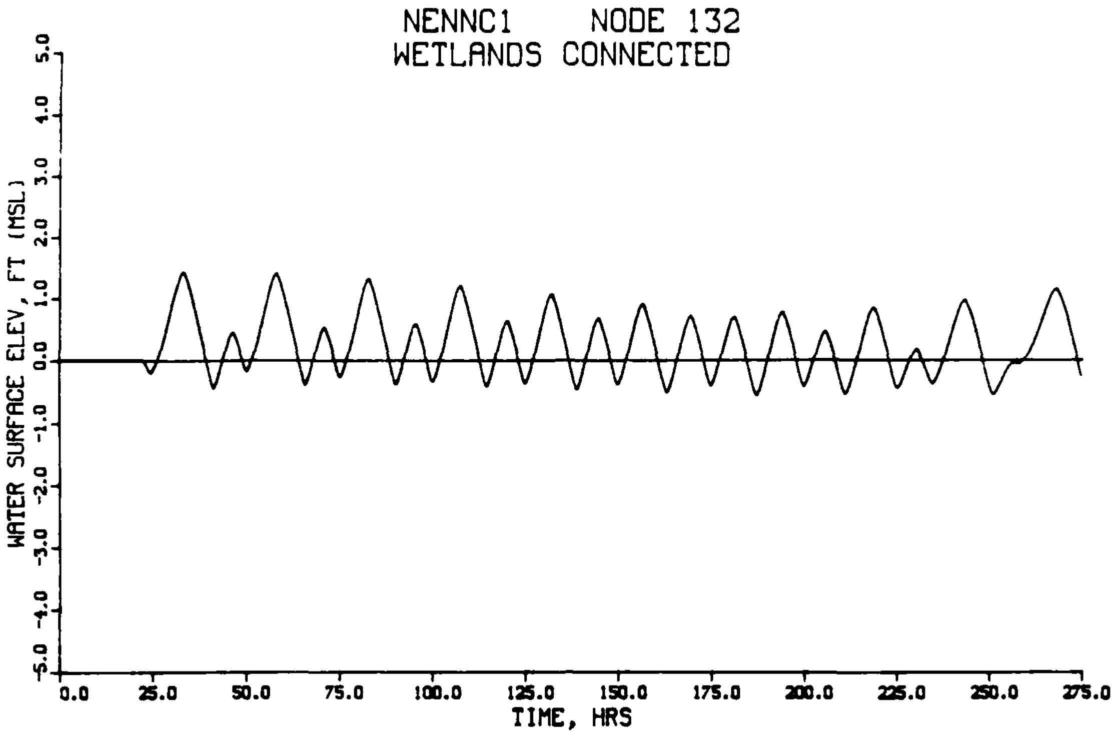
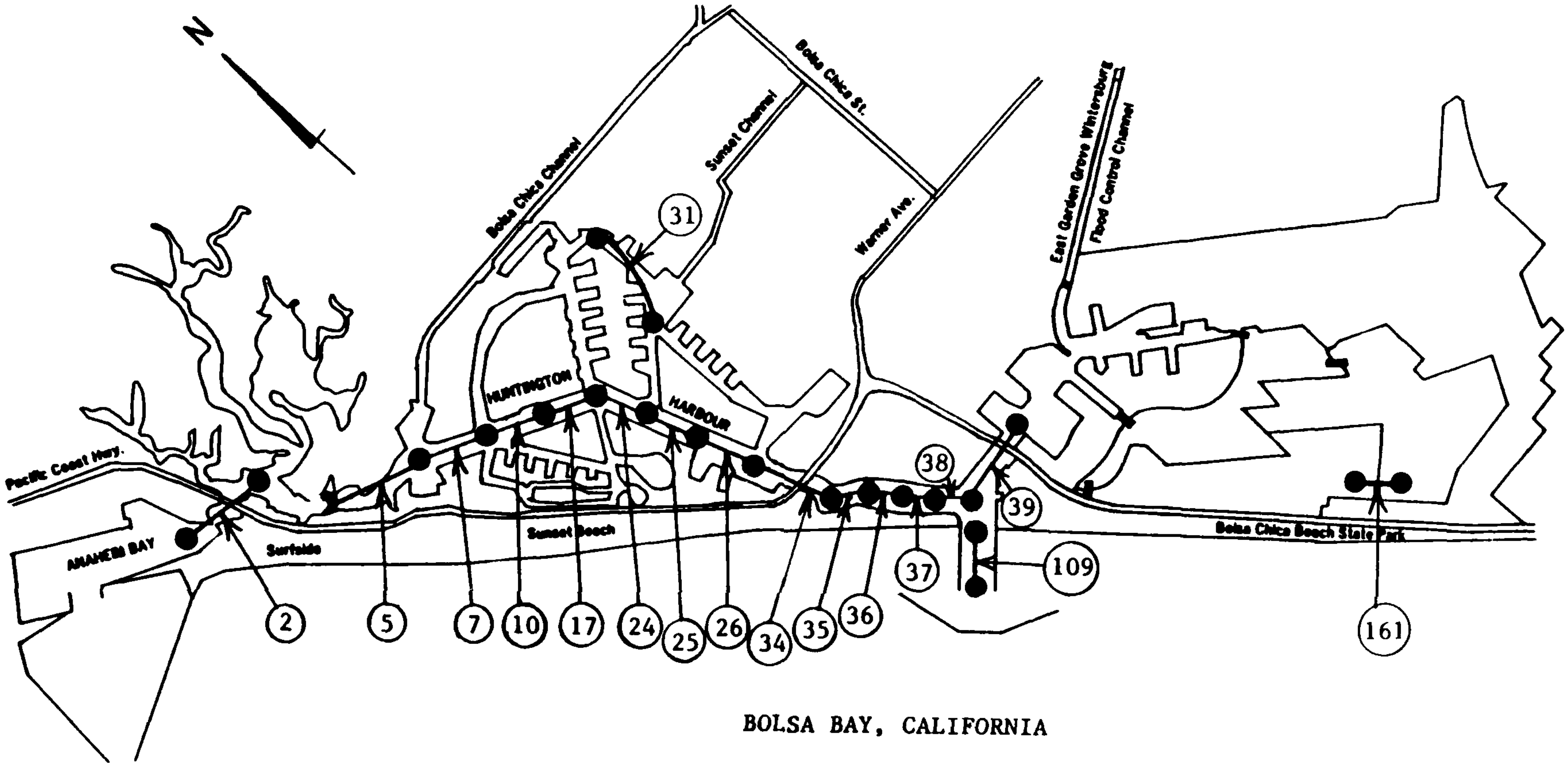


Figure 73. Tidal elevations in proposed muted tidal wetlands under navigable entrance channel and non-navigable connector channel to Huntington Harbour conditions, NENNCH1

Velocities

135. The locations of links for displaying pertinent average velocity simulation results are shown on Figure 74. Results of simulations for links of interest are displayed in Appendix F. Because a greater volume of the Huntington Harbour tidal prism can arrive from Anaheim Bay when Outer Bolsa Bay is allowed to remain in its present condition, a region of decreased average velocities in the channels of Huntington Harbour is less apparent than for the navigable connector channel concept. For the non-navigable connector channel condition, flood flow arrives at Node 25 through Link 26 (from Anaheim Bay) and through Link 34 (from Outer Bolsa Bay), and exits from Node 25 through Link 27. Hence, circulation develops around the channels of Huntington Harbour, and stagnation zones are even less likely to form.

136. The effects of the NENNC1 concept on typically representative average channel velocity time-histories are presented in Figures 75 through 80 for example displays in Huntington Harbour (Links 7, 17, and 26), at Warner Avenue bridge in its present location (Link 34), and in Outer Bolsa Bay



BOLSA BAY, CALIFORNIA

NENNC

Figure 74. Location of links for displaying average channel velocities under navigable entrance channel and non-navigable connector channel to Huntington Harbour conditions

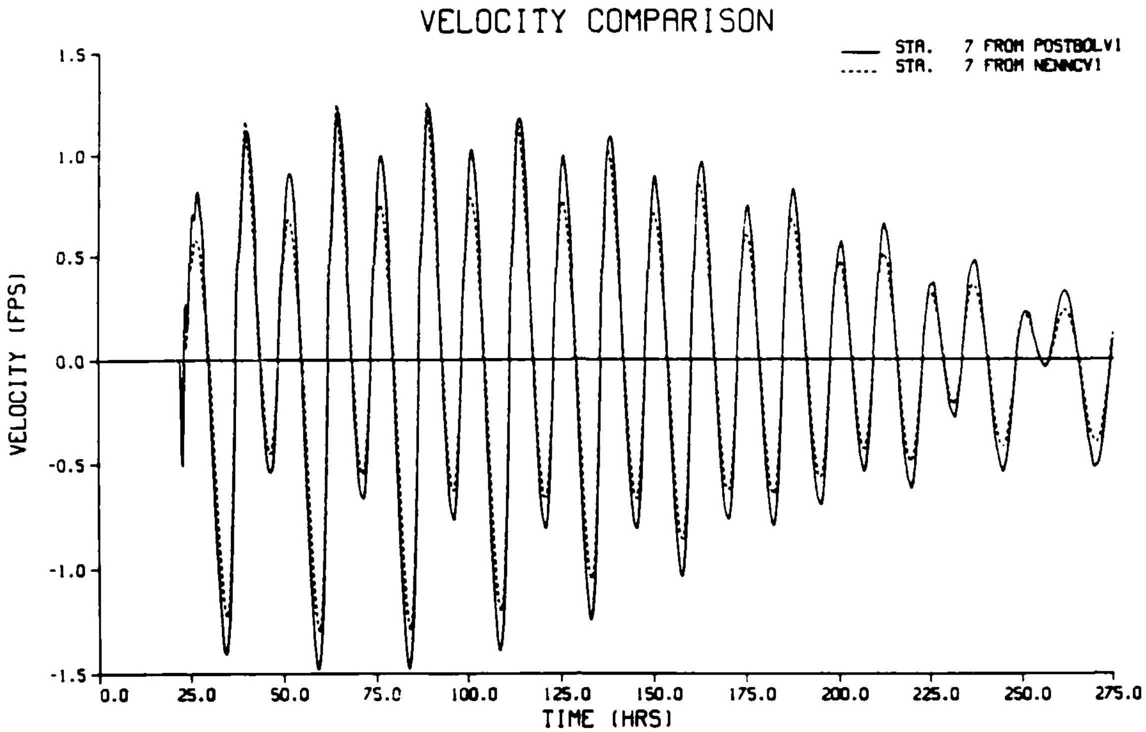


Figure 75. Average channel velocities in Huntington Harbour,
POSTBOL - existing condition
NENNCV1 - navigable entrance channel and non-navigable connector channel

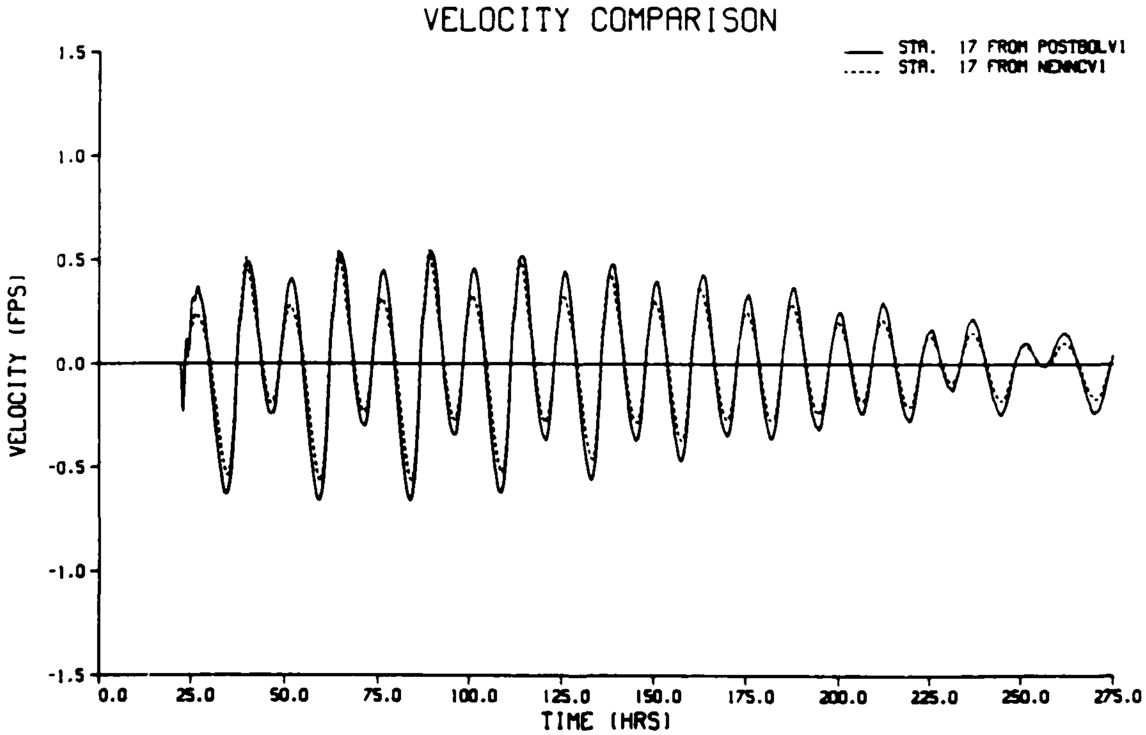


Figure 76. Average channel velocities in Huntington Harbour,
POSTBOL - existing condition
NENNCV1 - navigable entrance channel and non-navigable connector channel

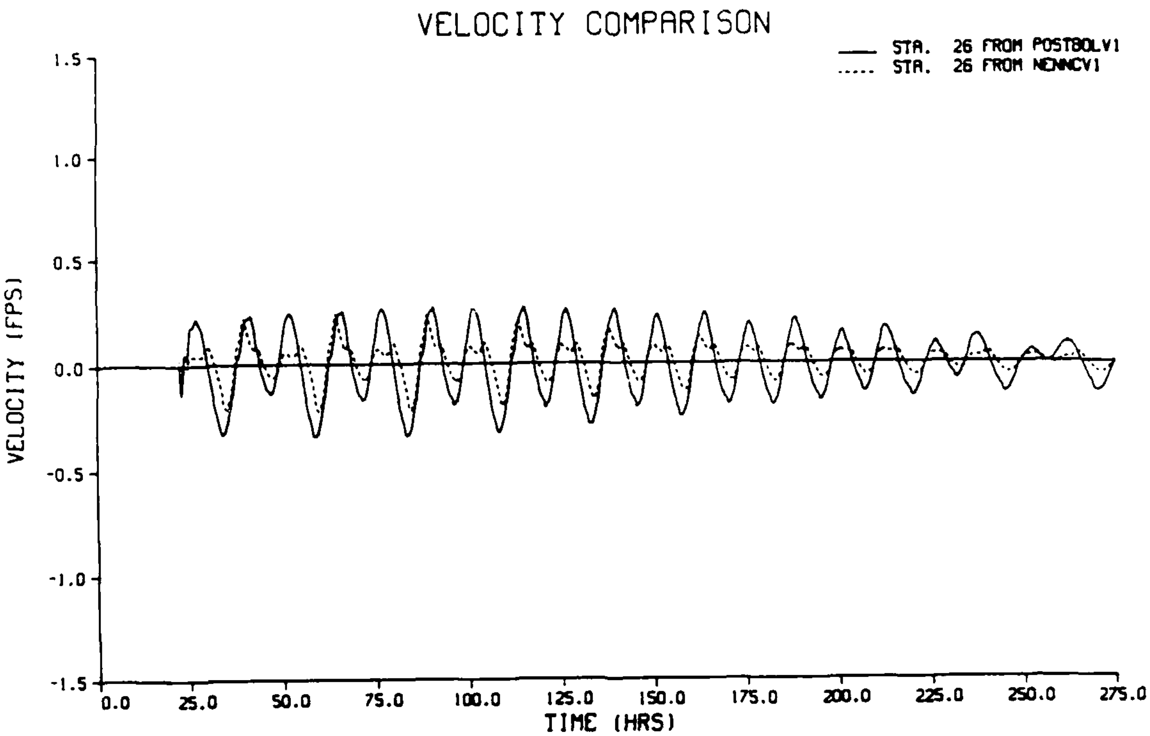


Figure 77. Average channel velocities in Huntington Harbour,
POSTBOL - existing condition
NENNCV1 - navigable entrance channel and non-navigable connector channel

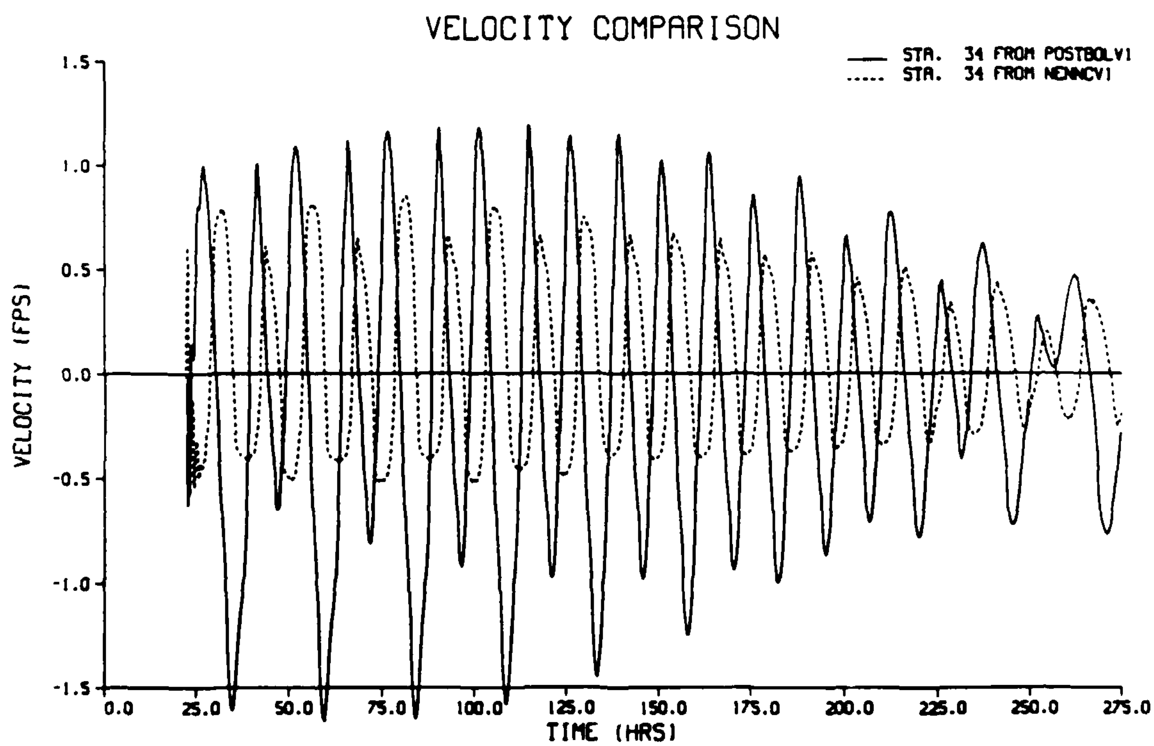


Figure 78. Average channel velocities at Warner Avenue bridge,
POSTBOL - existing condition
NENNCV1 - navigable entrance channel and non-navigable connector channel

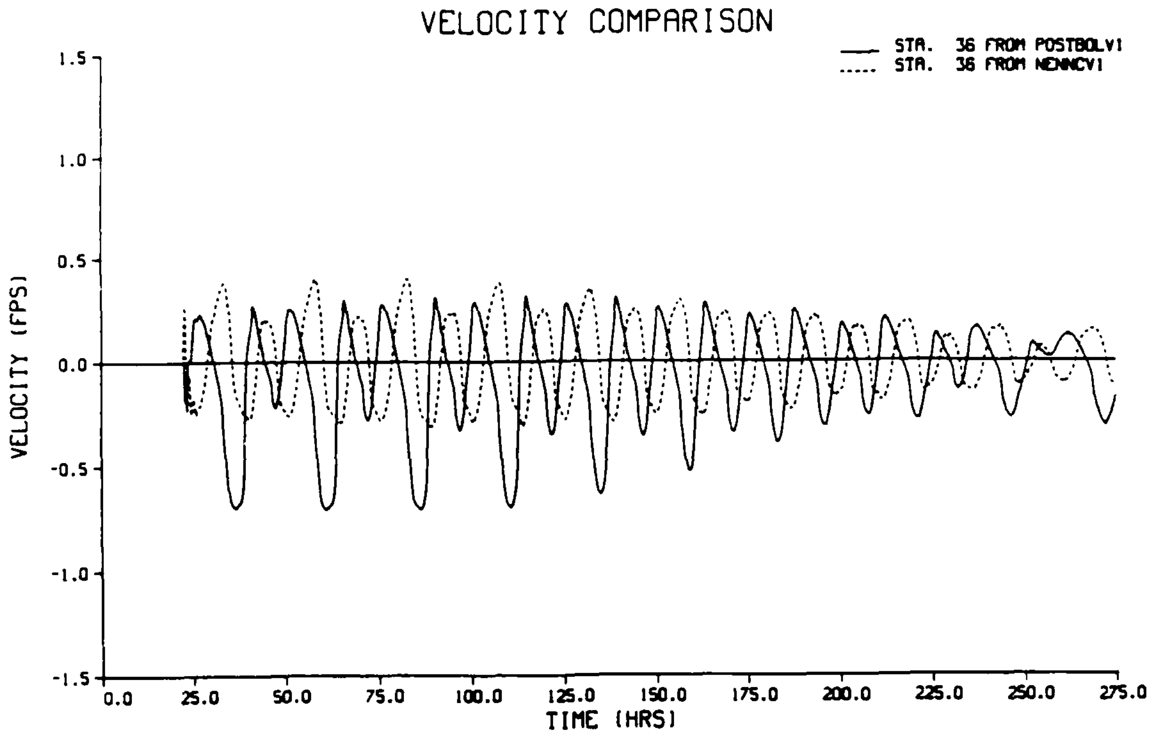


Figure 79. Average channel velocities in Outer Bolsa Bay,
POSTBOL - existing condition
NENNCV1 - navigable entrance channel and non-navigable connector channel

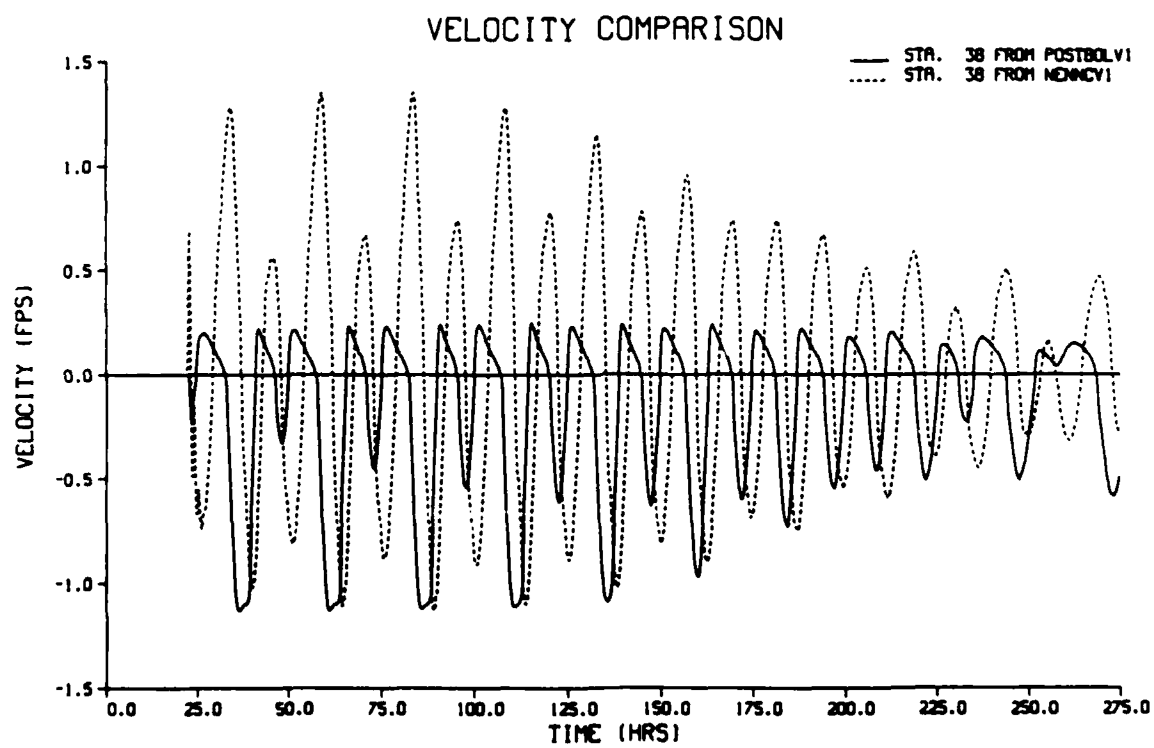


Figure 80. Average channel velocities in Outer Bolsa Bay,
POSTBOL - existing condition
NENNCV1 - navigable entrance channel and non-navigable connector channel

(Links 36 and 38), respectively. Maximum average channel velocities resulting from the NENNC1 concept for all links along the main Huntington Harbour channel and Outer Bolsa Bay are compared with existing condition velocities in Table 7.

Effect of wetlands connection

137. It has previously been shown (Figures 58 through 65) that, for the navigable entrance channel concept, any effects of connecting the existing muted tidal wetlands (Inner Bolsa Bay) with the proposed muted tidal wetlands by a Link 161 connecting Nodes 50 and 134 (created by a breach in the dike separating these two wetlands) would be confined to the vicinity of the wetlands. Effects would not propagate through the tide gates and culvert system into the marinas, Outer Bolsa Bay, or Huntington Harbour. While such a connection may impact circulation within the wetlands, any effect on tidal water surface elevations within the wetlands will be minor. A general circulation of flow through the wetlands system could be possible by a judicious operation of the tide gate control systems. The changes incurred by not creating a navigable connector channel to Huntington Harbour will not impact the ability of the 500-ft-wide navigable entrance channel to fully support the proposed marina and enhanced wetlands in a manner analogous to the 800-ft-wide navigable entrance channel. Since it has previously been shown that hydrodynamic effects of a wetlands connection will be minimal for the navigable entrance channel with a navigable connector channel to Huntington Harbour concept, such comparison displays of simulation data for the navigable entrance channel with a non-navigable connector channel to Huntington Harbour concept will not be repeated here.

Table 7

POSTBOL, Existing condition
versus
NENNC1, Navigable Entrance Channel
and Non-Navigable Connector Channel to Huntington Harbour

Wetlands Connected

Maximum Average Channel Velocities Along Main Channel System

Location	Link No	Maximum Average Channel Velocity ft per sec	
		POSTBOL	NENNC1
Pacific Coast Highway bridge	2	2.78	2.44
Huntington Harbour	5	1.42	1.24
Huntington Harbour	7	1.48	1.30
Huntington Harbour	10	0.71	0.62
Huntington Harbour	17	0.66	0.57
Huntington Harbour	24	0.57	0.45
Huntington Harbour	25	0.30	0.21
Huntington Harbour	26	0.34	0.18
Warner Avenue bridge	34	1.65	0.85
Outer Bolsa Bay	35	1.35	0.37
Outer Bolsa Bay	36	0.71	0.40
Outer Bolsa Bay	37	0.88	0.54
Outer Bolsa Bay	38	1.12	1.35
Entrance channel to marina	109	----	0.38

PART VII: NON-NAVIGABLE ENTRANCE CHANNEL CONCEPT

138. In certifying the Bolsa Chica Local Coastal Program (LCP) Land Use Plan (LUP) with suggested modifications, the California Coastal Commission (CCC) also certified an alternative plan (Secondary Alternative) with a non-navigable ocean entrance, and different internal use configurations than the modified Orange County LUP. This Secondary Alternative contains 915 acres of wetlands, a non-navigable ocean entrance, and a marina along the existing Warner Avenue on the Bolsa Chica Mesa. Ocean access would be through Huntington Harbour.

139. The CCC indicated that the Secondary Alternative could be certified as the LUP without further hearings if the proposed navigable ocean entrance was found to be infeasible pursuant to performance standards contained in the 29 November 1984 staff report, and substantially embodied in the LUP. As a result of CCC action, Orange County has incorporated the Secondary Alternative in the LUP as a land use option which the County would consider as a basis for an alternative LCP LUP, should the navigable ocean entrance prove overall to be infeasible as a result of the Land Use Plan Confirmation process. LUP Policy 25 requires submittal of an evaluation of this alternative as part of the Land Use Plan Confirmation.

Hydraulic and Wetland Design Features

140. CCC developed the conceptual design of the wetland for the non-navigable entrance channel alternative (McGrath 1987), and transmitted these data to SLC, noting "...we have developed a map that should allow WES to proceed to the modeling stage..." Because certain critical details necessary for accurately simulating the design in the numerical model were not specified, WES requested SLC to provide these additional design parameters. At a meeting of 30 November 1987 (Weaver 1987) among CCC, SLC, DFG, Orange County Environmental Management Agency, and Moffatt & Nichol, Engineers, the requested details were developed and transmitted to WES by SLC. Weaver (1987) discusses each of the pertinent design characteristics.

East Garden Grove-Wintersburg Flood Control Channel (EGG-WFCC)

141. The hydrology for EGG-WFCC is the same as that for the navigable entrance alternative. A channel downstream of the tide gates 250 ft wide at the bottom is necessary to convey the 100-year design flood flows (9,710 cfs), and should have a constant bottom elevation of -5 ft msl. Further study of the sediment transport capacity of the channel may indicate that a deeper channel may be advisable to trap sediment before it reaches the non-navigable entrance, wetlands, or marina areas.

Non-navigable entrance channel

142. CCC noted there may be reduced tidal prism available to aid in keeping the non-navigable entrance open, since most water areas in the wetland will be muted (as desired by DFG). Also, if littoral deposits partially or completely close the non-navigable entrance channel, EGG-WFCC flows will bypass through Huntington Harbour. It was recognized that the entrance channel cannot be sized based on flood flows alone. It was concurred to use an entrance channel 160 ft wide at the bottom, with a bottom elevation of -5 ft msl. A major consideration was the intent of CCC to keep the channel dimensions to a minimum, subject to later verification studies.

Marina and connector channels

143. A 25-acre marina basin would be located adjacent to Warner Avenue. A connector channel between the marina and EGG-WFCC was proposed to reduce velocities through Outer Bolsa Bay to avoid potential scouring of existing sediments in this wetland area. Should the non-navigable entrance channel close, all wetland tidal prism flow will be required to pass through Outer Bolsa Bay and/or this connector channel. Velocities may become excessive and the potential effects should be evaluated. A channel 70 ft wide at the bottom with a bottom elevation of -5 ft msl was recommended for study. It was suggested that WES model the plan both with and without the marina connector channel.

Wetland design

144. The CCC conceptual wetland design of the proposed additional muted tidal area was considered to be appropriate for the non-navigable entrance channel alternative. No significant grading of the interior of the proposed additional muted tidal area was anticipated, with the exception of the existing raised oil roads which should be assumed to be removed completely at

the end of project phasing, according to DFG. SLC indicated that WES should consider the proposed additional muted tidal wetlands (310 acres) to be analogous to the existing full and muted tidal wetlands (142 acres) in elevation-area relationship. Accordingly,

Existing Full and Muted Tidal Wetlands

Elevation (ft, msl)	-3.5	-2.3	-0.3	1.8	4.5
Area (acres)	1.7	6.3	44.4	122.6	142.0

Proposed Additional Muted Tidal Wetlands

Elevation (ft, msl)	-3.5	-2.3	-0.3	1.8	4.5
Area (acres)	3.7	13.8	96.9	267.6	310.0

The storage curves for these wetlands are displayed in Figure 81, and the plan layout is shown in Figure 82. The wetland design will remain the same for the Secondary Alternative (non-navigable entrance channel) with or without a connector channel between the proposed marina near Warner Avenue and the EGG-WFCC relocation. The above elevation-area relationships were installed in the numerical model for the proposed wetland enhancement designs.

Culvert designs

145. The non-navigable entrance channel concept provides for connecting the entrance channel and Outer Bolsa Bay with the existing muted tidal wetlands (Inner Bolsa Bay) by a system of 4-ft-diam culverts (3 pipes in, 4 pipes out) at an invert elevation of -5.1 ft msl. Also, a circulation channel connects the entrance channel and EGG-WFCC with the proposed muted tidal wetlands by a 4-ft-diam culvert system (3 pipes in, 4 pipes out) at an invert elevation of -5 ft msl.

NNECC
Non-Navigable Entrance Channel and By-Pass Connector Channel to Marina

Tidal elevations

146. Water surface elevations from simulations at significant nodes of interest are displayed in Appendix G. Since tidal elevations are already well known in Huntington Harbour, only those nodes at the ends of the main harbor channel are displayed. Primary interest in this regard is directed toward the ability of the non-navigable entrance channel concept to fully support the proposed muted wetland enhancement plan for this concept. An

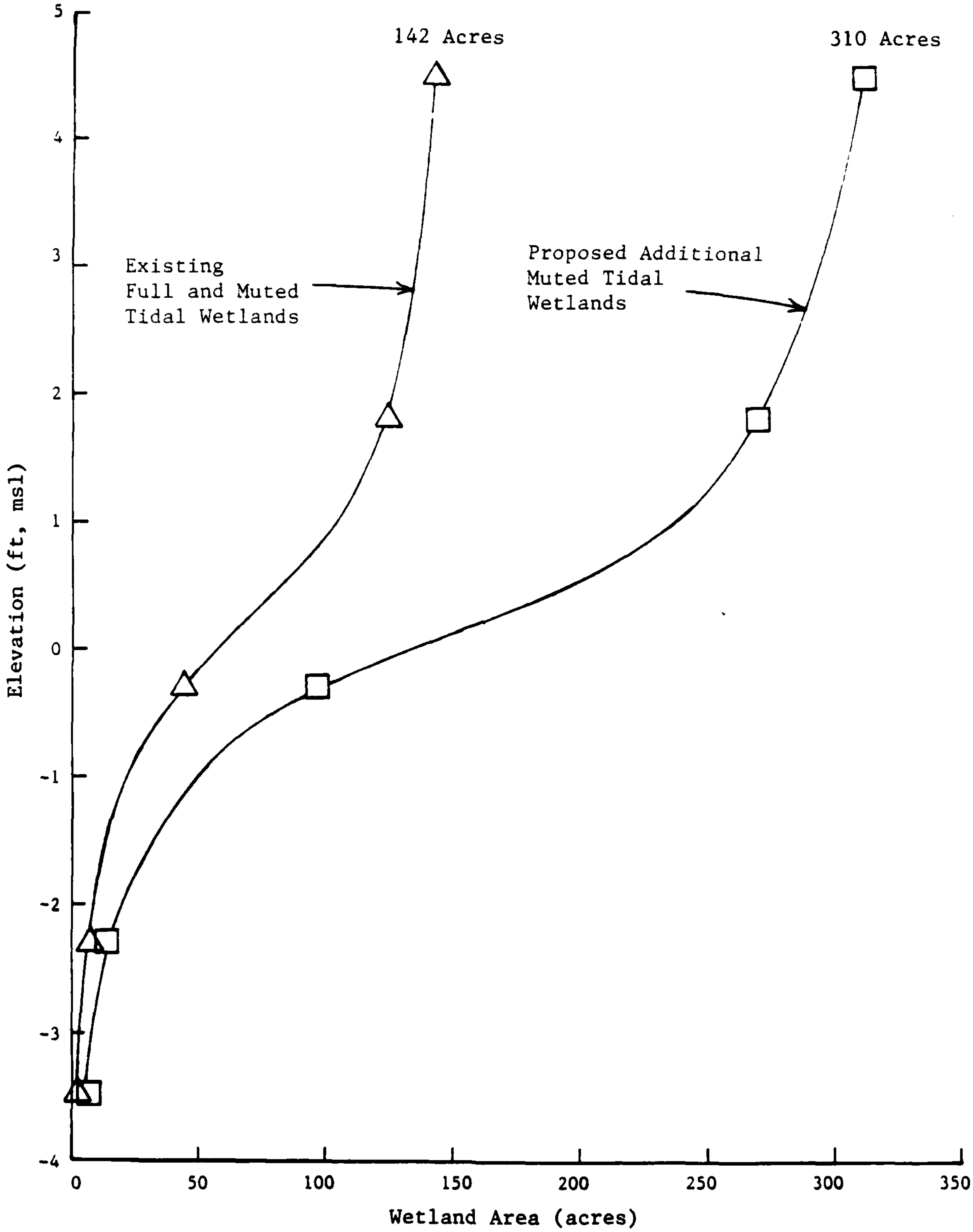


Figure 81. Elevation-area relationship of existing and proposed wetland enhancement areas, non-navigable entrance channel concept, NNECC

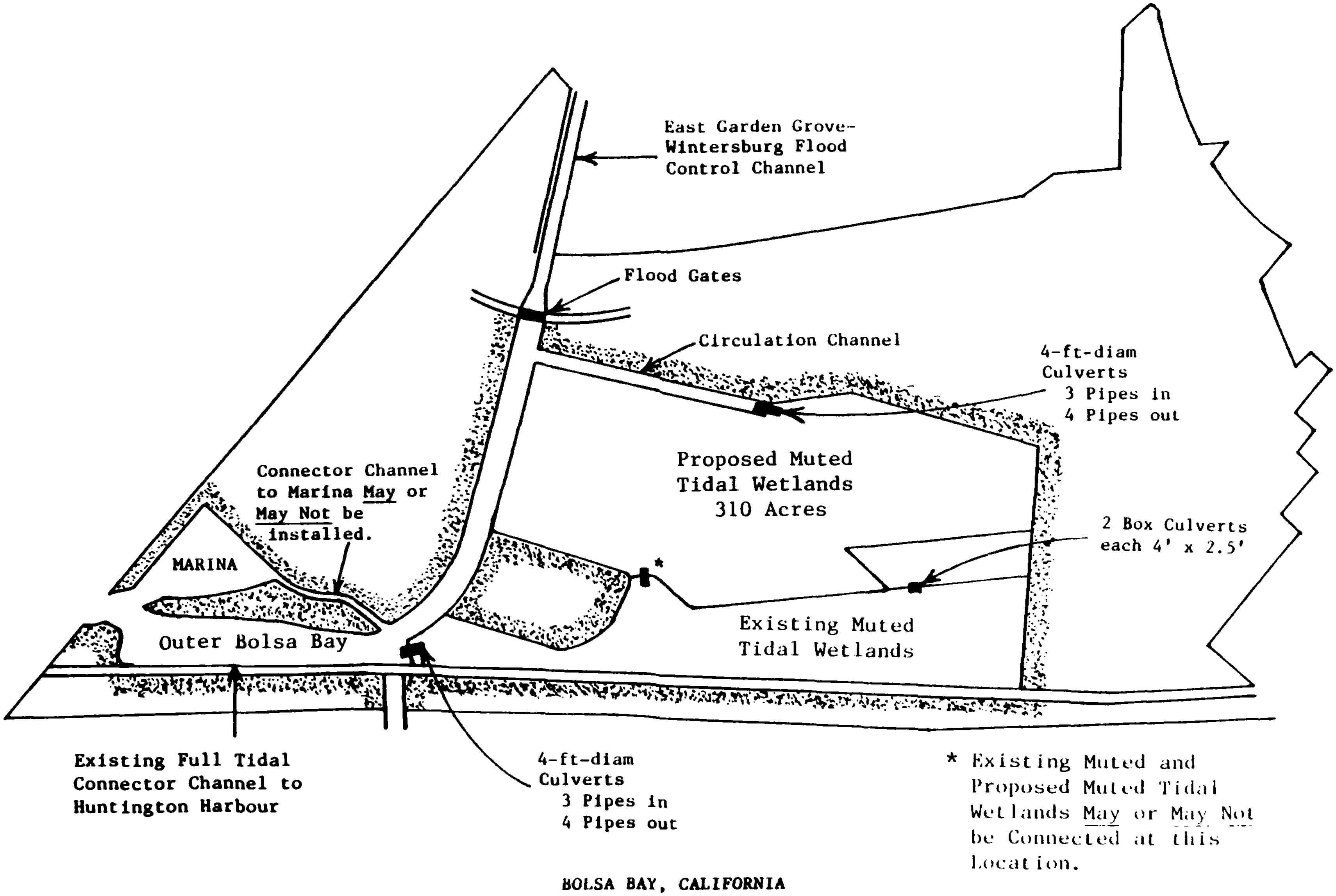
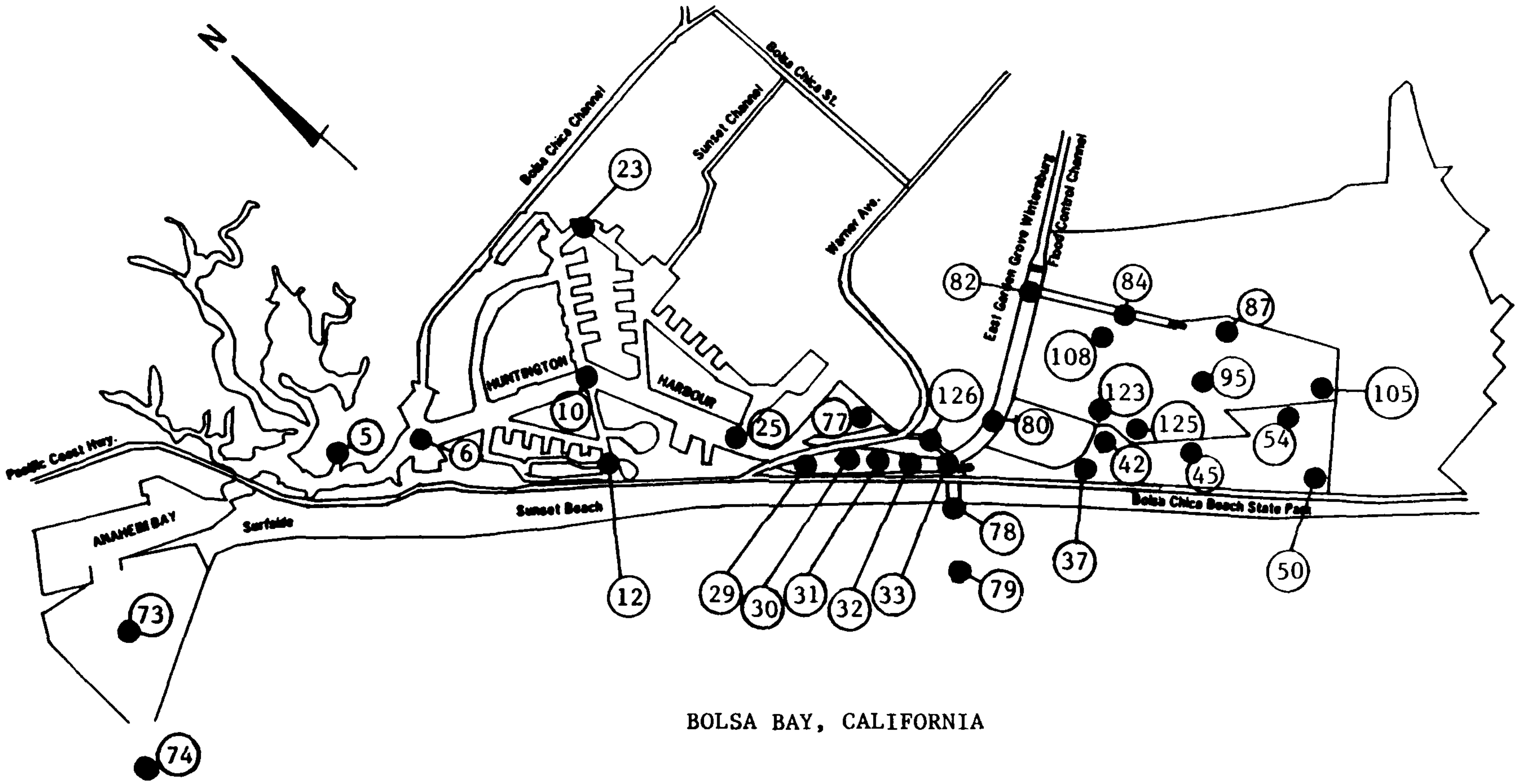


Figure 82. Secondary Alternative, non-navigable entrance channel with non-navigable connector channel to Huntington Harbour concept, NNECC, and proposed wetland enhancement areas



BOLSA BAY, CALIFORNIA

NNECC

Figure 83. Location of nodes for displaying water surface elevations under non-navigable entrance channel and by-pass connector channel to marina conditions

array of nodes is displayed throughout all regions of the existing and proposed muted tidal wetlands, through Outer Bolsa Bay, and along both the EGG-WFCC channel and the conveyance channel to the proposed muted wetlands.

147. The effect of the NNECC3 concept on typically representative water surface elevation time-histories are presented in Figures 84 through 87 for Huntington Harbour (Node 10), Outer Bolsa Bay (Node 32), Inner Bolsa Bay (Node 37), and the DFG muted tidal cell (Node 54), respectively. Time-histories of water surface elevations in the channel to the proposed muted tidal wetlands (Node 84), in the muted tidal wetlands (Node 95), and in the by-pass connector channel to the marina (Node 126), are shown in Figures 88 through 90, respectively. Tidal ranges at representative regions throughout the bay system are presented in Table 8.

Table 8

NNECC3
Non-Navigable Entrance Channel
and By-Pass Connector Channel to Marina

Wetlands Connected

Tide Ranges at Representatives Nodes

Location	Node No	High Tide feet, msl	Low Tide feet, msl
Huntington Harbour	10	4.10	-4.10
Outer Bolsa Bay	29	4.10	-4.10
Outer Bolsa Bay	30	4.10	-3.53
Outer Bolsa Bay	31	4.09	-3.44
Outer Bolsa Bay	32	4.09	-3.37
Outer Bolsa Bay	33	4.09	-3.10
Inner Bolsa Bay	37	1.14	-0.32
Inner Bolsa Bay	45	1.13	-0.28
Inner Bolsa Bay	50	1.14	-0.29
DFG muted tidal cell	54	1.10	0.02
Proposed marina	77	4.10	-4.01
EGG-WFCC	82	4.09	2.72
Channel to muted tidal wetlands	84	4.09	2.03
Proposed muted tidal wetlands	95	1.14	-0.32
Proposed muted tidal wetlands	108	1.14	-0.32
By-pass channel to marina	126	4.10	-3.17

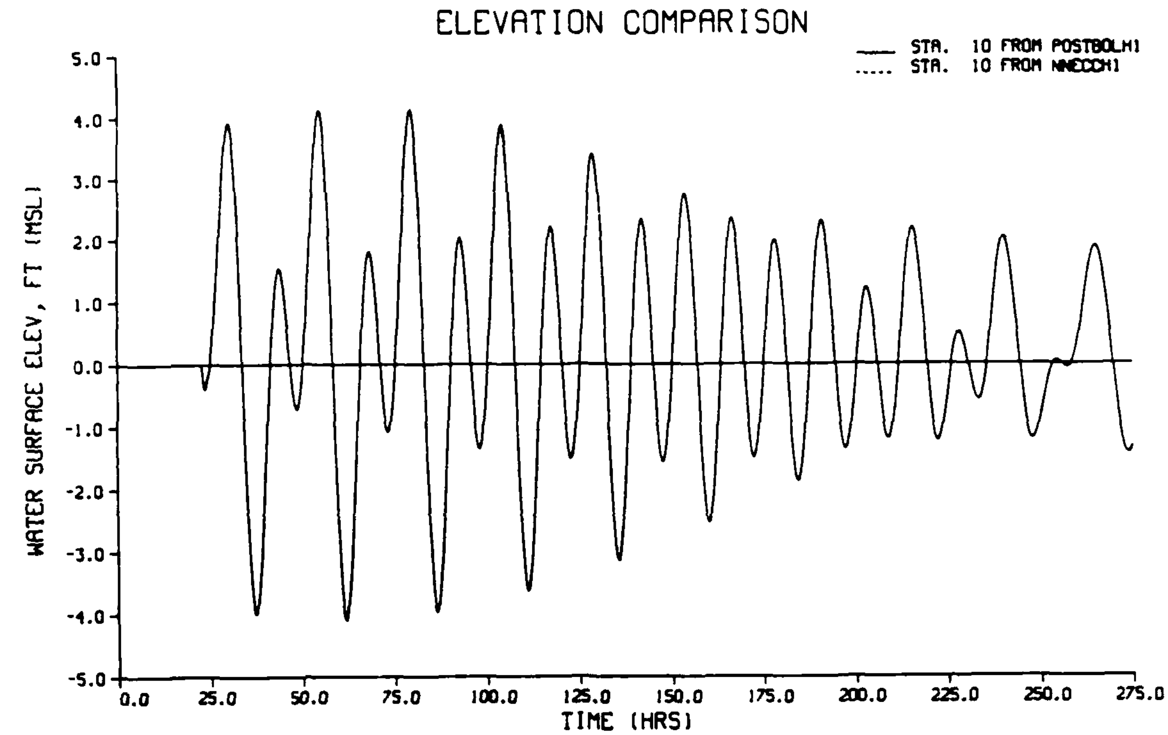


Figure 84. Tidal elevations in Huntington Harbour,
POSTBOL - existing condition
NNECCH1 - non-navigable entrance channel and by-pass connector to marina

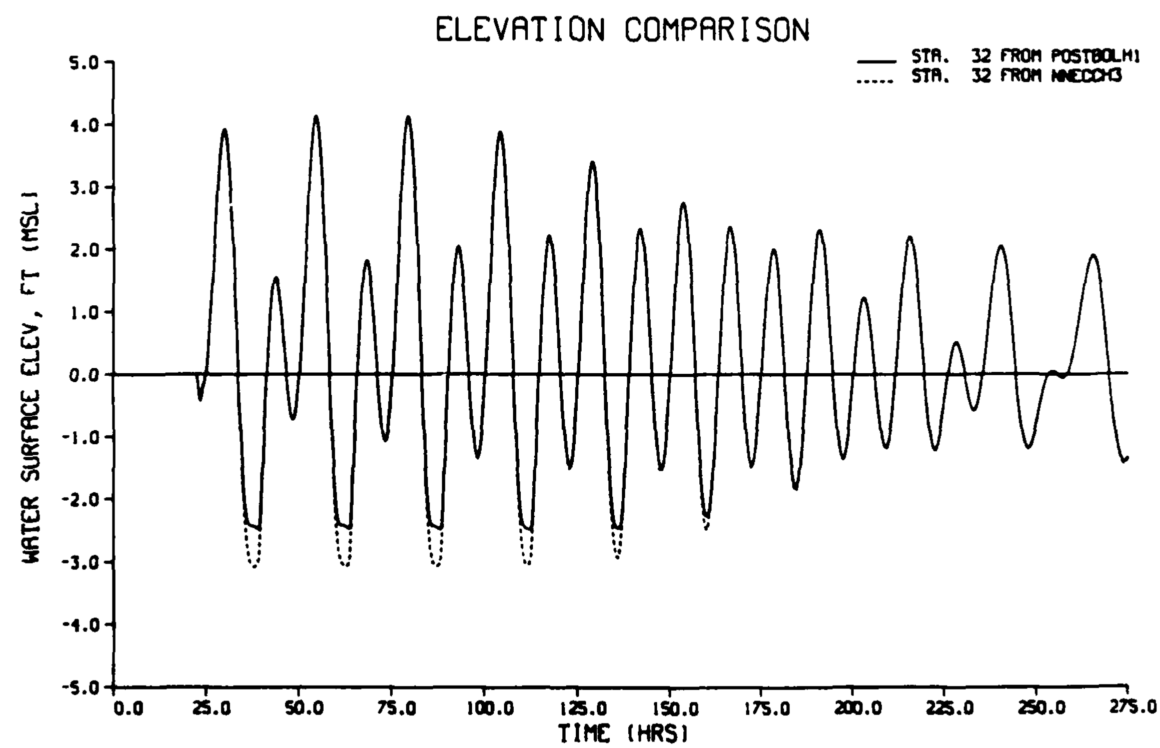


Figure 85. Tidal elevations in Outer Bolsa Bay,
POSTBOL - existing condition
NNECCH1 - non-navigable entrance channel and by-pass connector to marina

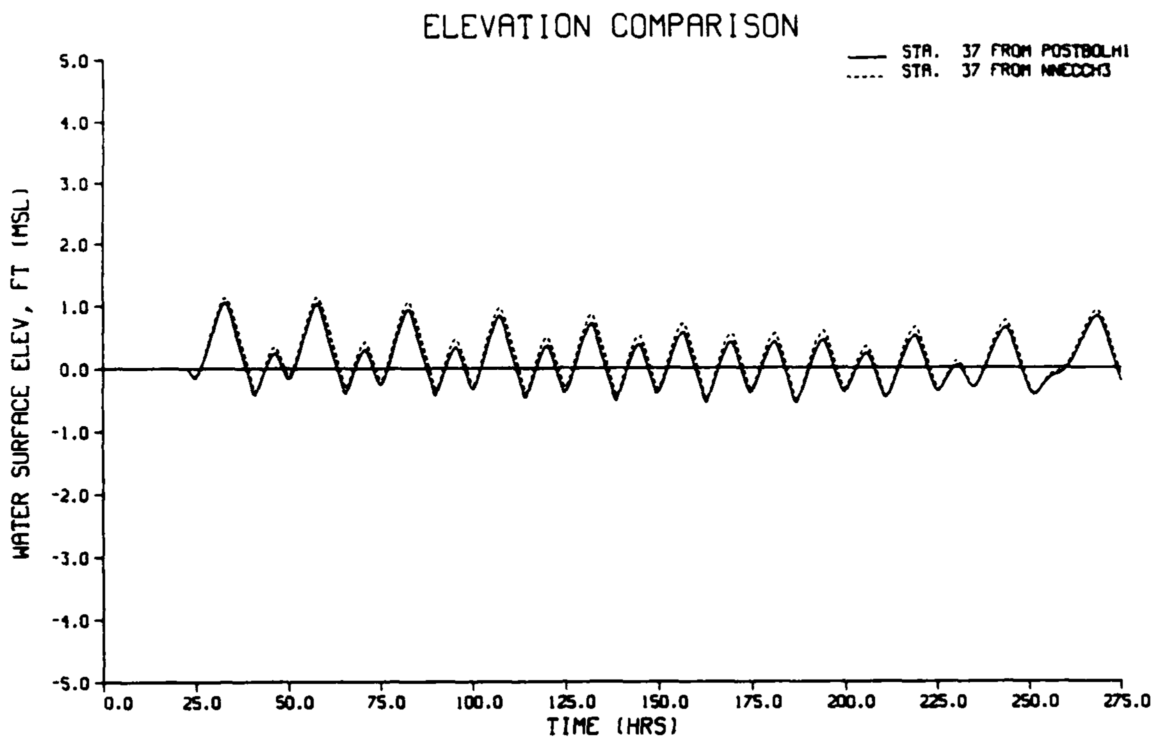


Figure 86. Tidal elevations in Inner Bolsa Bay,
POSTBOL - existing condition
NNECCH1 - non-navigable entrance channel and by-pass connector to marina

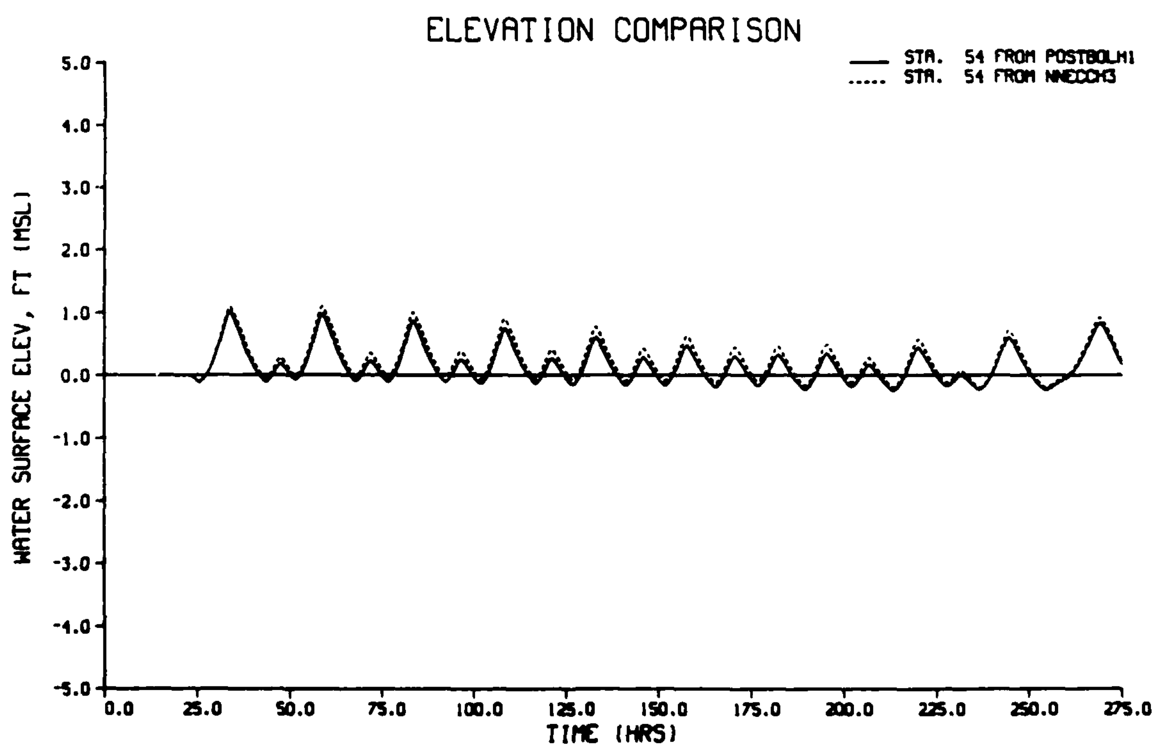


Figure 87. Tidal elevations in DFG muted tidal cell,
POSTBOL - existing condition
NNECCH1 - non-navigable entrance channel and by-pass connector to marina

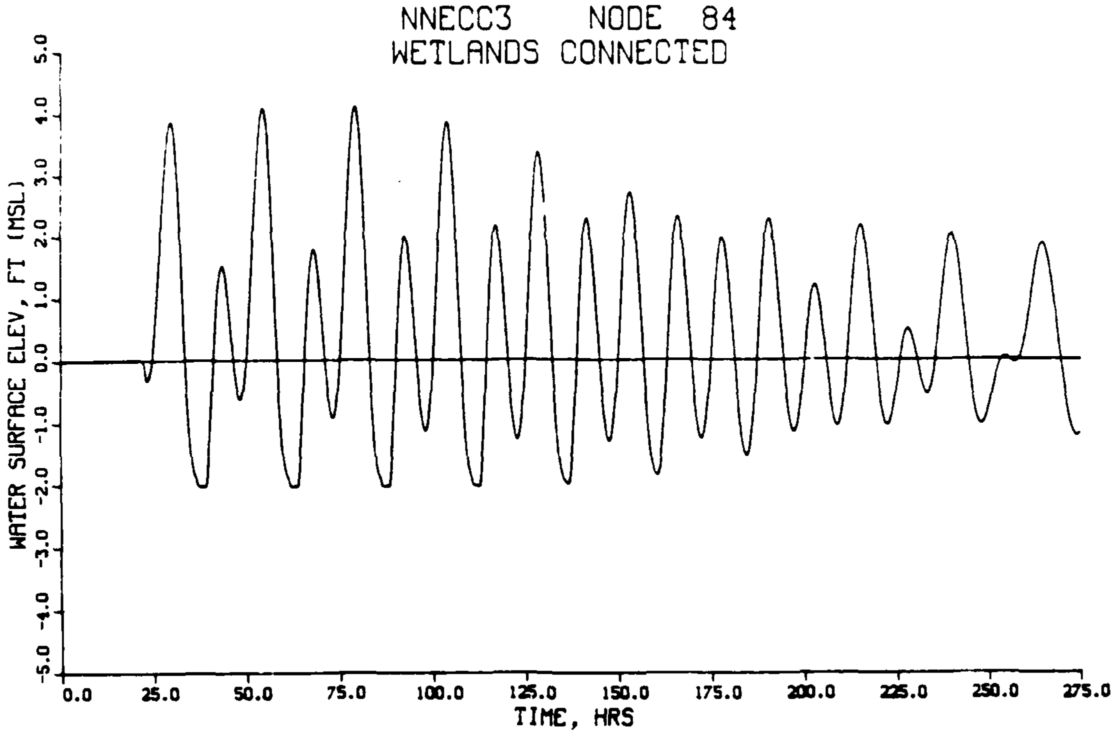


Figure 88. Tidal elevations in channel to proposed muted tidal wetlands under non-navigable entrance channel and by-pass connector channel to proposed marina conditions, NNECCH1

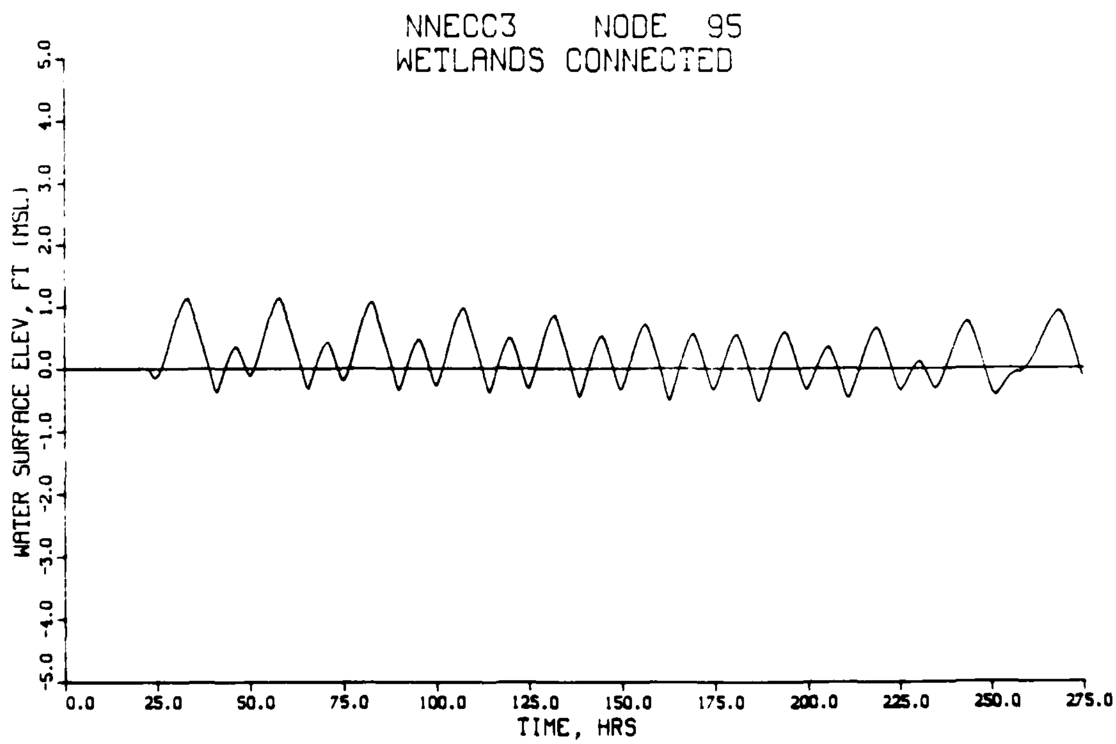


Figure 89. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance channel and by-pass connector channel to proposed marina conditions, NNECCH1

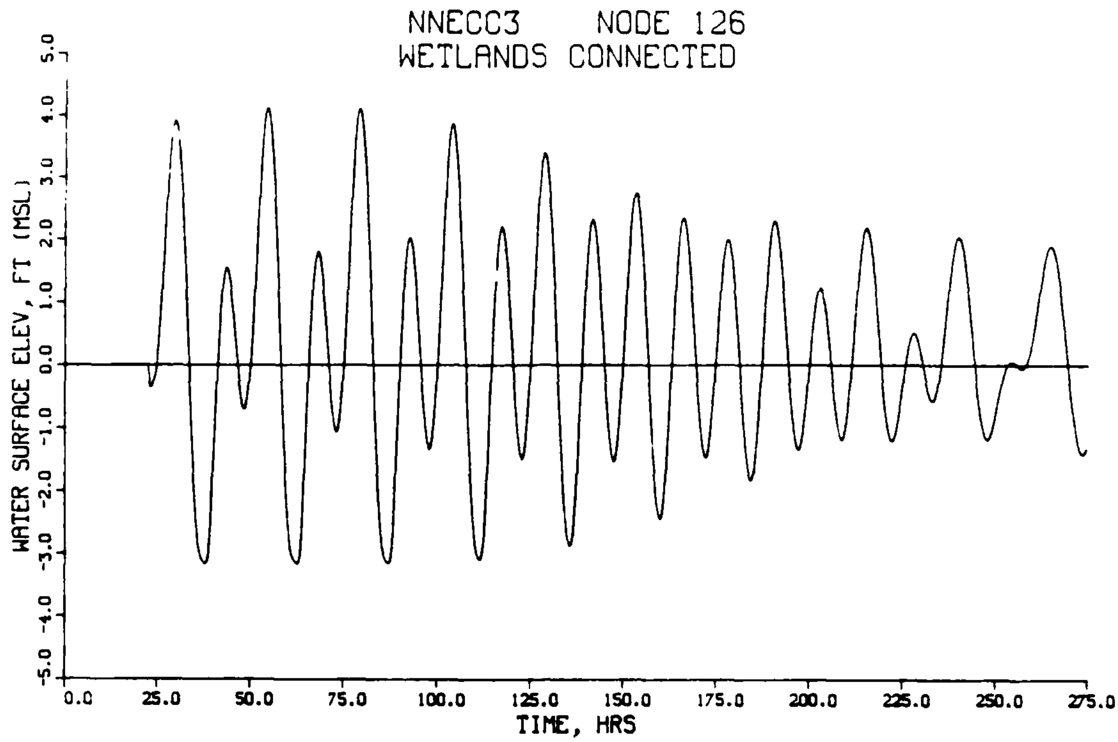
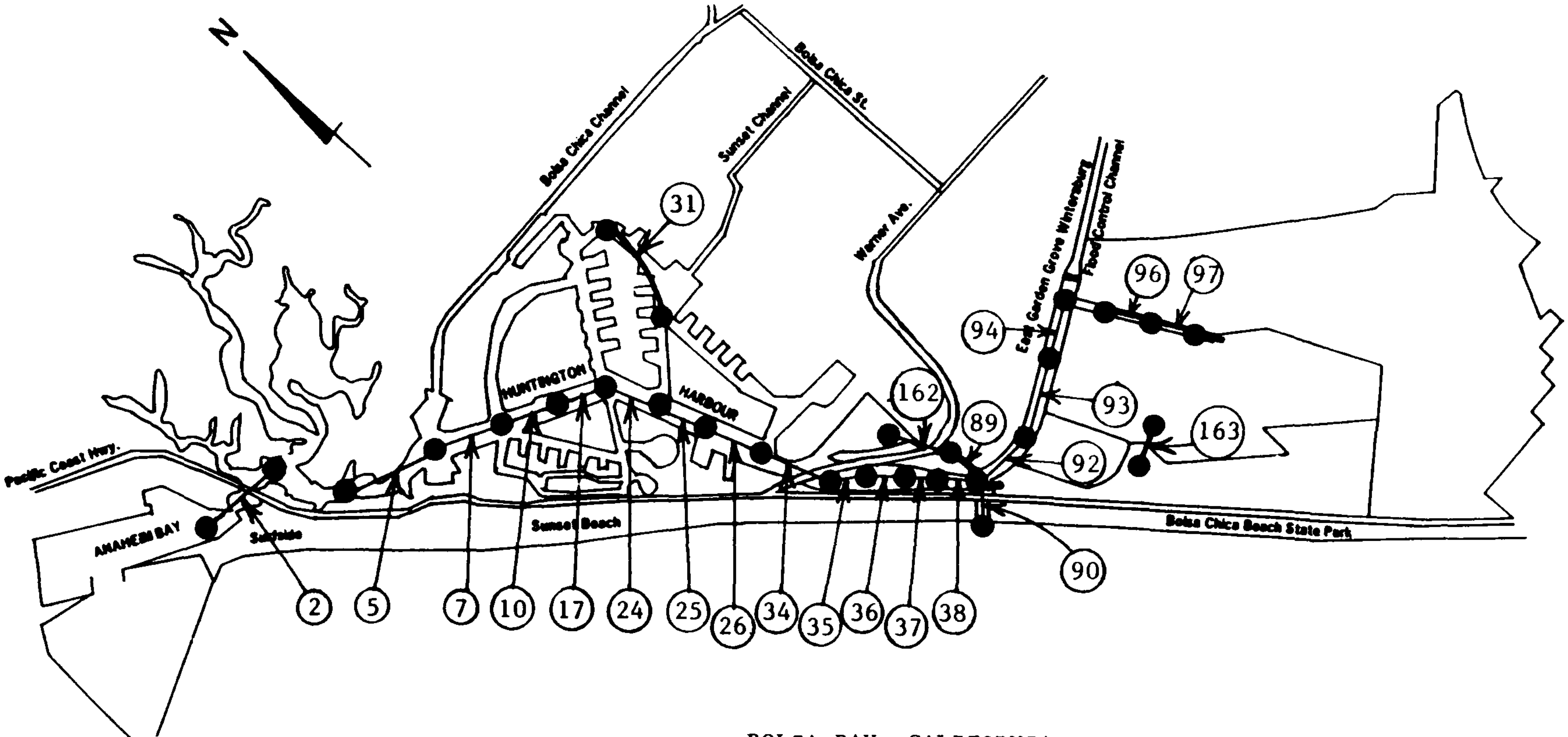


Figure 90. Tidal elevations in by-pass channel to proposed marina under non-navigable entrance channel conditions, NNECCH1

Velocities

148. Average channel velocities at significant links of interest are presented in Appendix H. These displays closely approximate the existing condition simulations for Huntington Harbour. Actually, the velocities for the condition of non-navigable entrance channel and non-navigable connector channel to the marina are slightly greater (both ebb and flood) in Huntington Harbour than for the existing condition. This implies that a small portion of the wetlands tidal prism may be traversing through Anaheim Bay, although by far the greater amount of the tidal prism enters and exits by way of the proposed new non-navigable entrance channel. Most of the proposed marina tidal prism will be required to pass through Huntington Harbour, and this constitutes much of the velocity increase here. Link 34 experiences a far different condition. Warner Avenue bridge has been removed, the PCH rerouted, and Link 34 significantly enlarged. It will be shown later by comparison plots of these estimates with other plans that velocities for this proposed plan compare closely with existing conditions in Huntington Harbour.



BOLSA BAY, CALIFORNIA

NNECC

Figure 91. Location of links for displaying average channel velocities under non-navigable entrance channel and by-pass connector channel to marina conditions

149. Maximum average channel velocities resulting from the NNECC3 concept for all links along the main Huntington Harbour channel and Outer Bolsa Bay are compared with existing condition velocities in Table 9. The effects of the NNECC3 concept on typically representative average channel velocity time-histories are presented in Figures 92 through 99 for example displays in Huntington Harbour (Links 7, 17, and 26), at the location of the previous Warner Avenue bridge (Line 34), in Outer Bolsa Bay (Links 36 and 38), and in the by-pass connector channel to the marina (Links 89 and 162), respectively.

Table 9

POSTBOL, Existing Condition
versus
NNECC3, Non-Navigable Entrance Channel
and By-Pass Connector Channel to Marina

Wetlands Connected

Maximum Average Channel Velocities Along Main Channel System

		Maximum Average Channel Velocity ft per sec	
Location	Link No	POSTBOL	NNECCH3
Pacific Coast Highway bridge	2	2.78	2.82
Huntington Harbour	5	1.42	1.53
Huntington Harbour	7	1.48	1.63
Huntington Harbour	10	0.71	0.79
Huntington Harbour	17	0.66	0.74
Huntington Harbour	24	0.57	0.69
Huntington Harbour	25	0.30	0.39
Huntington Harbour	26	0.34	0.48
Warner Avenue bridge	34	1.65	0.51
Outer Bolsa Bay	35	1.35	1.13
Outer Bolsa Bay	36	0.71	0.65
Outer Bolsa Bay	37	0.88	0.51
Outer Bolsa Bay	38	1.12	0.90
Non-navigable entrance channel	90	----	1.33
EGG-WFCC	94	----	0.57
Channel to muted tidal wetlands	97	----	1.40
By-pass channel to marina	89	----	1.31
By-pass channel to marina	162	----	1.82

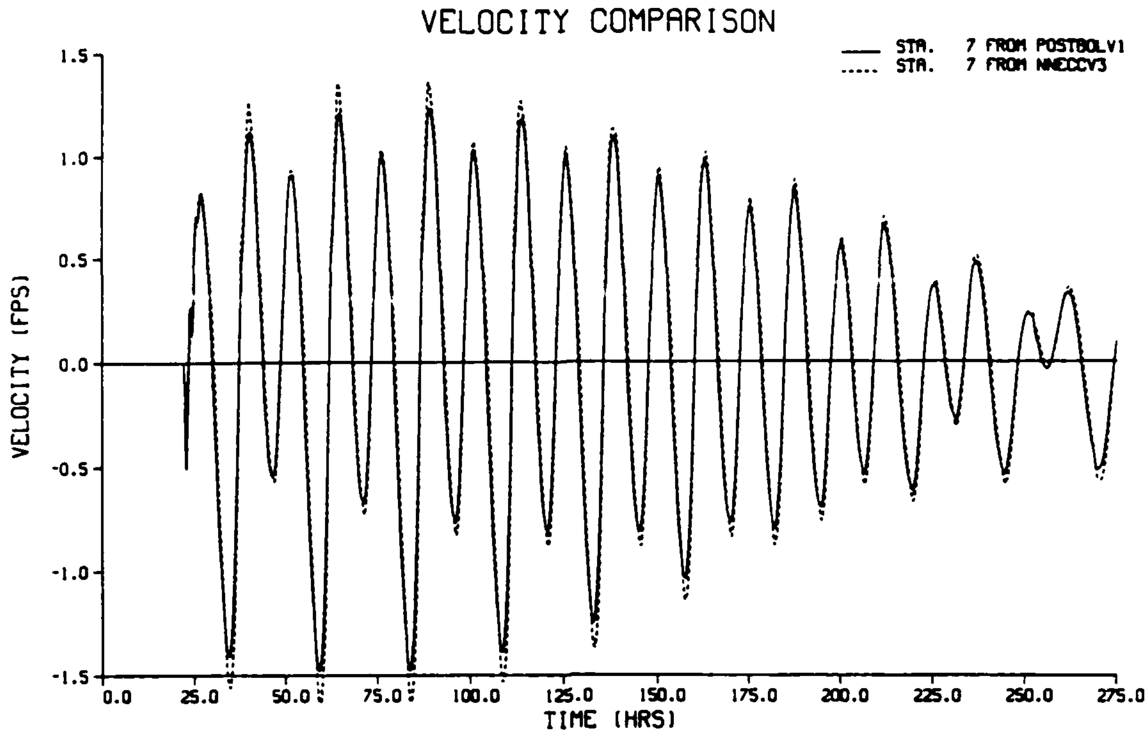


Figure 92. Average channel velocities in Huntington Harbour,
POSTBOL - existing condition
NNECCV3 - non-navigable entrance channel and by-pass connector to marina

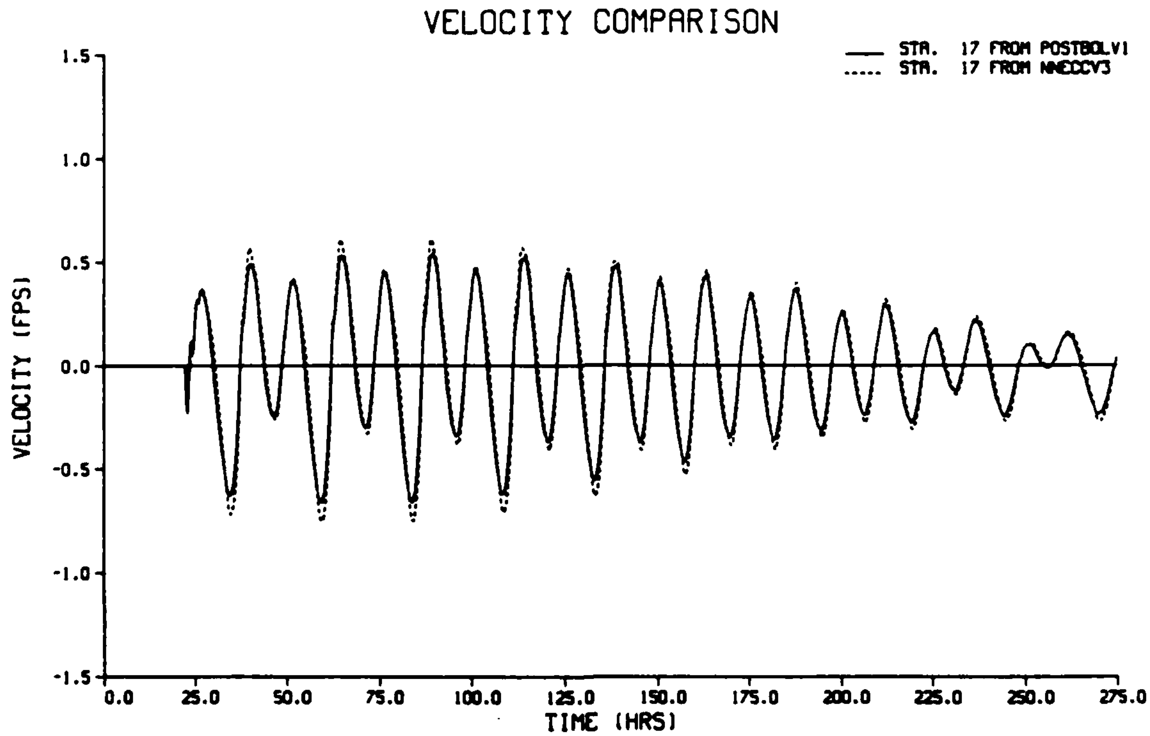


Figure 93. Average channel velocities in Huntington Harbour,
POSTBOL - existing condition
NNECCV3 - non-navigable entrance channel and by-pass connector to marina

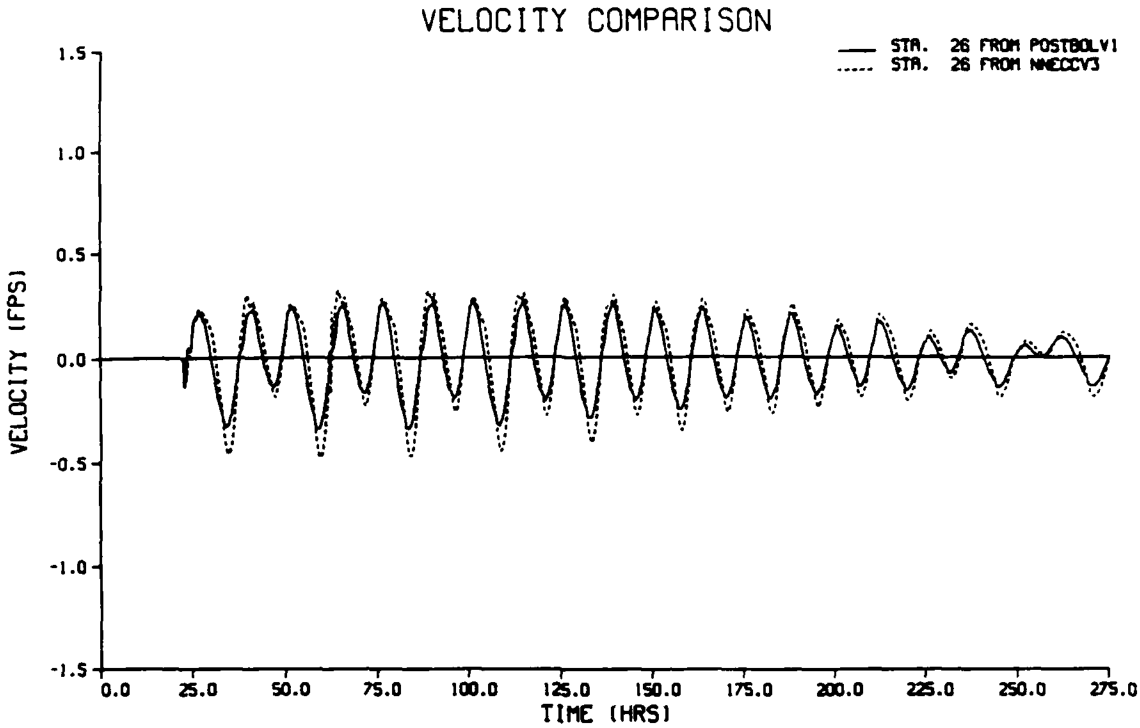


Figure 94. Average channel velocities in Huntington Harbour,
POSTBOL - existing condition
NNECCV3 - non-navigable entrance channel and by-pass connector to marina

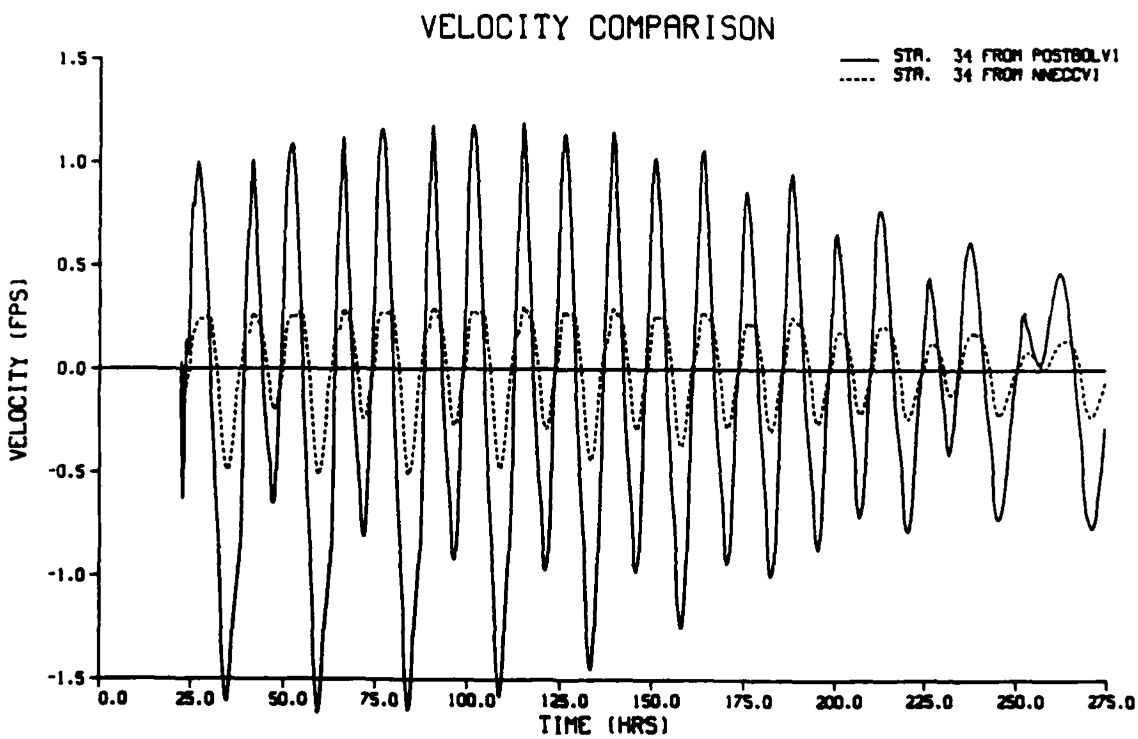


Figure 95. Average channel velocities at Warner Avenue bridge,
POSTBOL - existing condition
NNECCV3 - non-navigable entrance channel and by-pass connector to marina

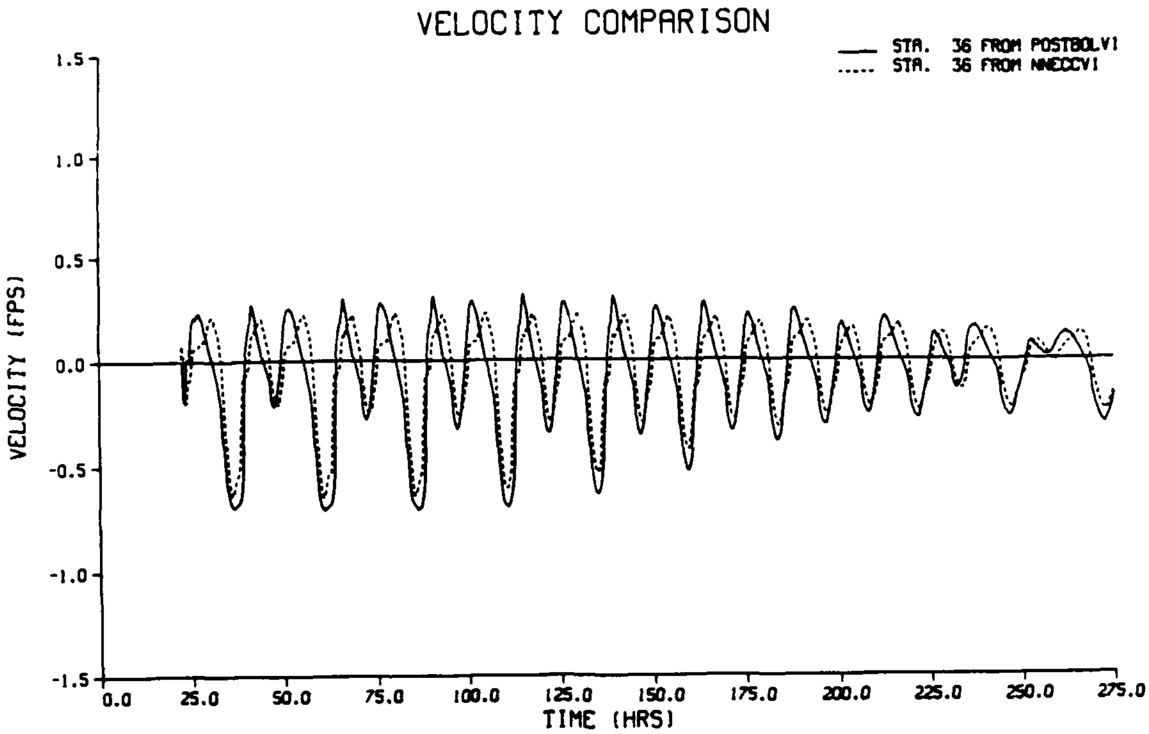


Figure 96. Average channel velocities in Outer Bolsa Bay,
POSTBOL - existing condition
NNECCV3 - non-navigable entrance channel and by-pass connector to marina

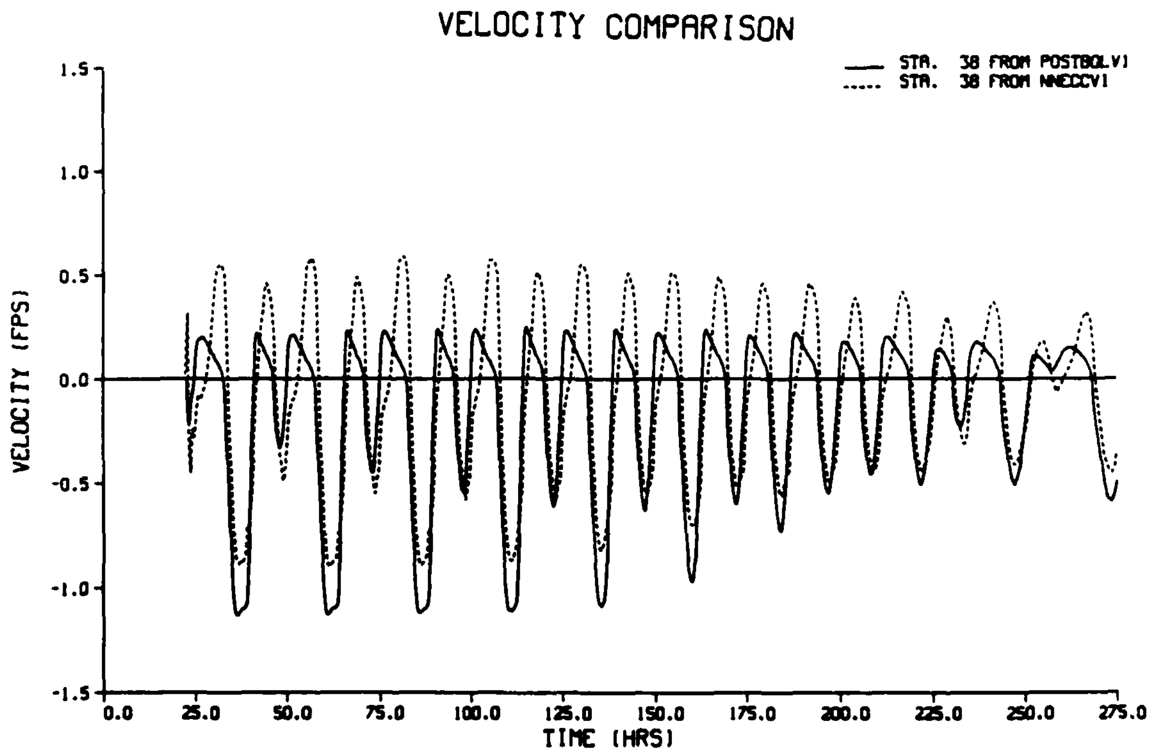


Figure 97. Average channel velocities in Outer Bolsa Bay,
POSTBOL - existing condition
NNECCV3 - non-navigable entrance channel and by-pass connector to marina

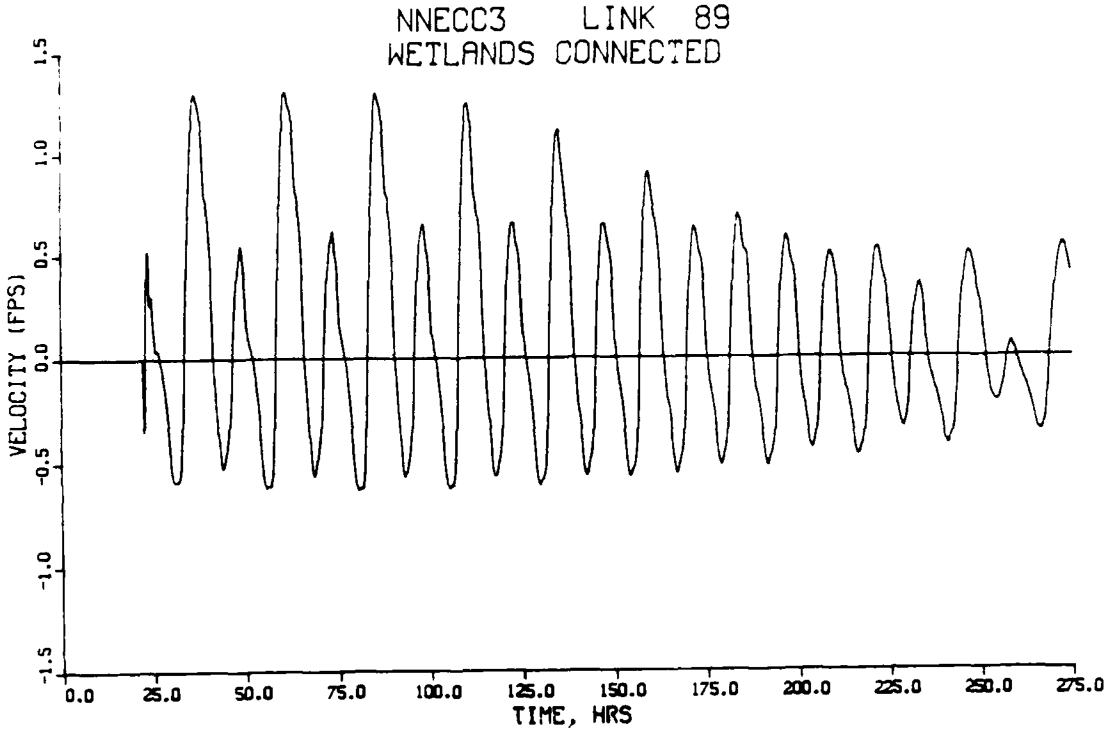


Figure 98. Average channel velocities in by-pass channel to proposed marina under non-navigable entrance channel conditions, NNECCV3

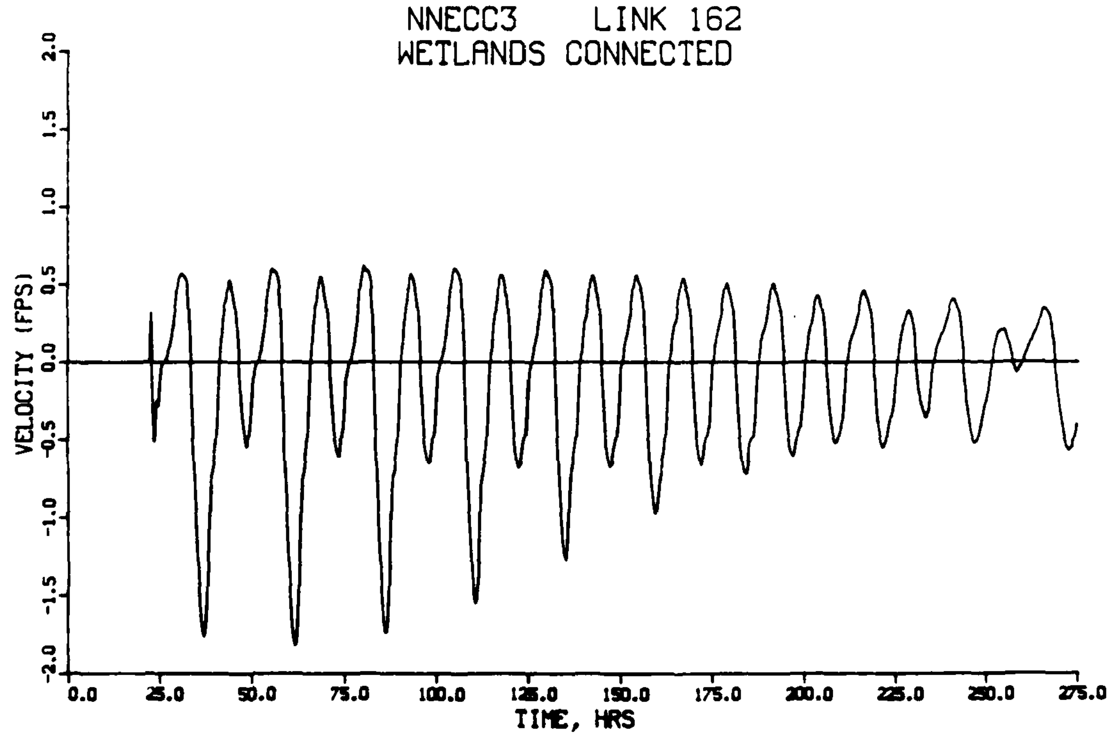


Figure 99. Average channel velocities in by-pass channel to proposed marina under non-navigable entrance channel conditions, NNECCV3

Effect of wetlands connection

150. Existing Inner Bolsa Bay may or may not be connected to the proposed muted tidal wetland enhancement by an opening through the dike along Link 163 connecting Nodes 42 and 123. The **DYNTRAN** simulations were performed both with and without this wetland connection. Here again, as for the navigable entrance channel concept, it was determined that any effects created by such connections within the wetlands would not propagate through the culvert and tide gate system into the EGG-WFCC channel, Outer Bolsa Bay, or other regions of the complex. Any effects within the wetlands will remain within the wetlands.

151. A perceptible change occurs to the water surface elevations within the wetlands when Inner Bolsa Bay is connected to the proposed muted tidal wetlands. Because Inner Bolsa Bay is significantly smaller than the proposed muted tidal wetlands, but at this time having the same tide gate arrangement and operation, it becomes essentially a source of flow for filling and emptying the tidal prism of the proposed new muted wetlands. Accordingly, when the two wetlands are connected by Link 163, Inner Bolsa Bay experiences about a 15 percent reduction in both water surface rise and fall. At the same time, the proposed new muted wetlands experience a 5 to 8 percent increase in both water level rise and fall. When the two separate wetland systems become one large circulation complex, continuity requires that an equilibrium water surface condition be established. Estimates from pertinent nodes are displayed in Figures 100 through 105.

152. Figure 100 indicates an imperceptible change in water surface elevations in Outer Bolsa Bay. A reduction in tidal fluctuation in the existing muted wetlands (Inner Bolsa Bay) of about 15 percent is shown in Figure 101. The tidal fluctuations in the channel to the proposed muted tidal wetlands are displayed in Figure 102, where it is seen that the effects of a wetland connection are not detectable. Figures 103 through 105 are simulations in the proposed muted tidal wetlands, and the slight increases in tidal fluctuations of about 5 to 8 percent when the wetlands are connected is apparent throughout the wetland area.

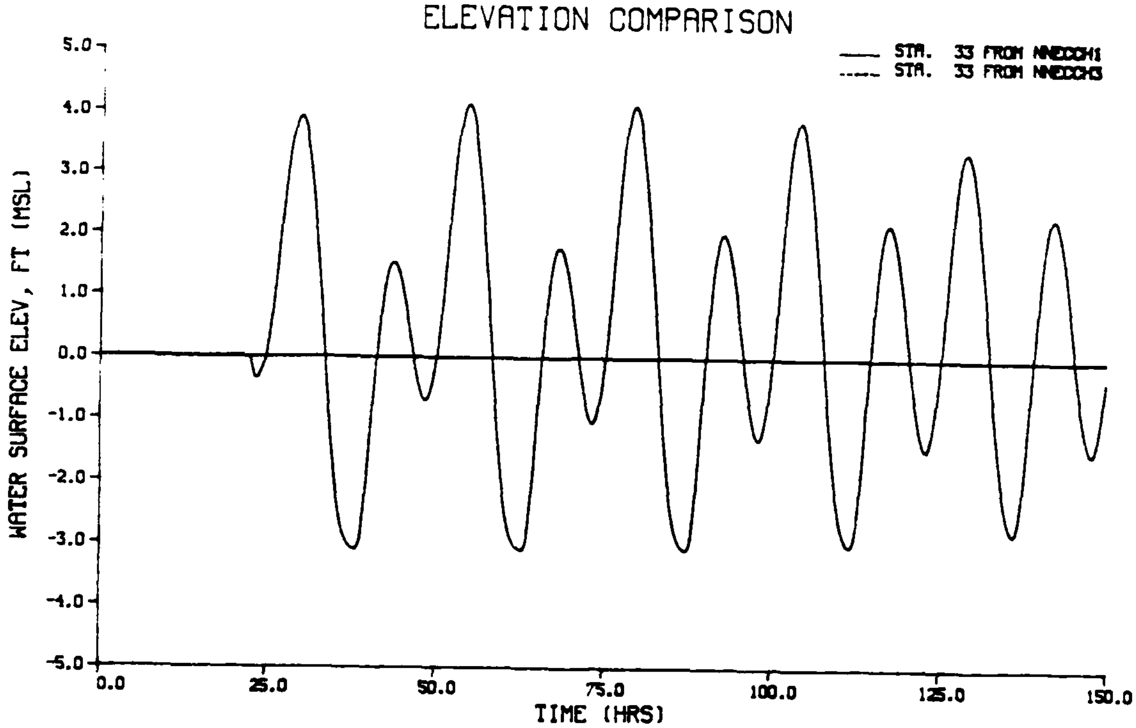


Figure 100. Effect of wetlands connection on tidal elevations, Outer Bolsa Bay, non-navigable entrance and by-pass channel to marina, NNECCH1 - wetlands not connected, NNECCH3 - wetlands connected

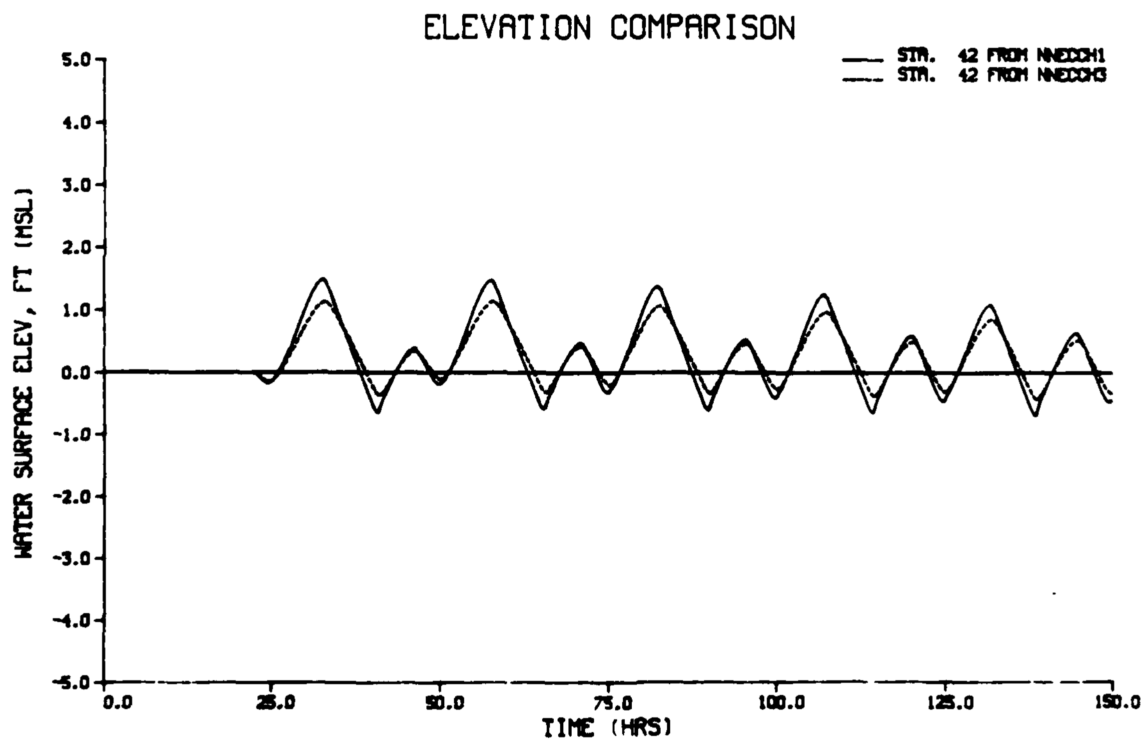


Figure 101. Effect of wetlands connection on tidal elevations, Inner Bolsa Bay, non-navigable entrance and by-pass channel to marina, NNECCH1 - wetlands not connected, NNECCH3 - wetlands connected

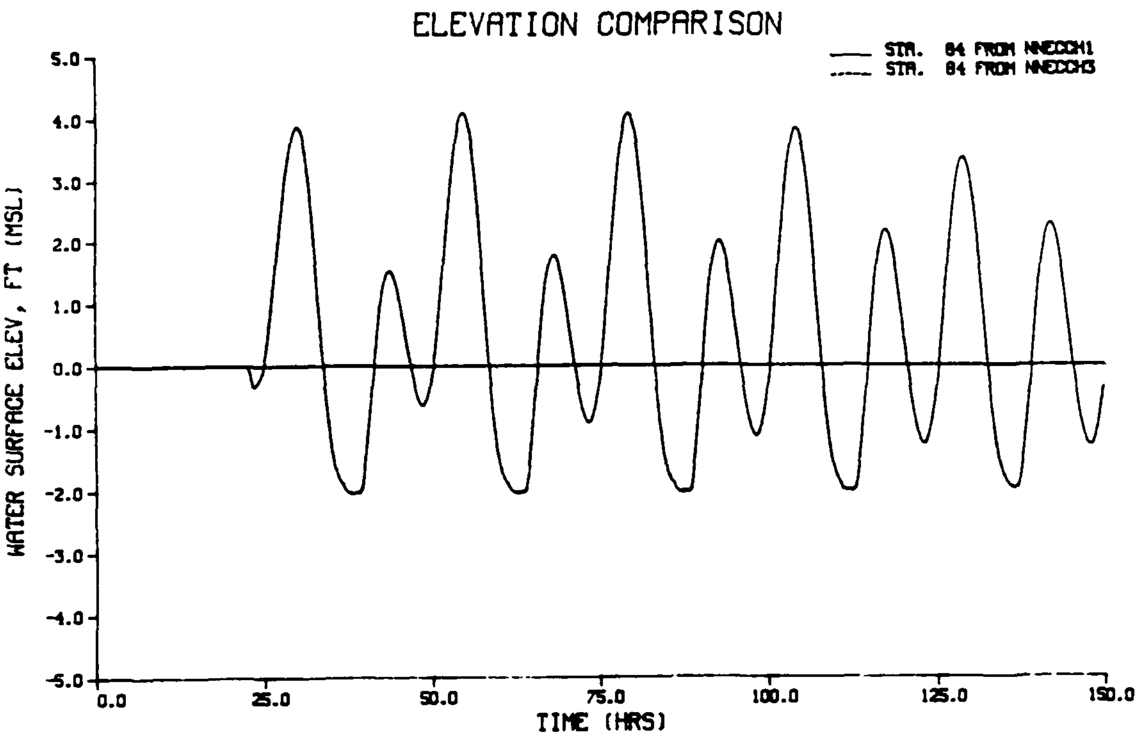


Figure 102. Effect of wetlands connection on tidal elevations, proposed marina, non-navigable entrance and by-pass channel to marina, NNECCH1 - wetlands not connected, NNECCH3 - wetlands connected

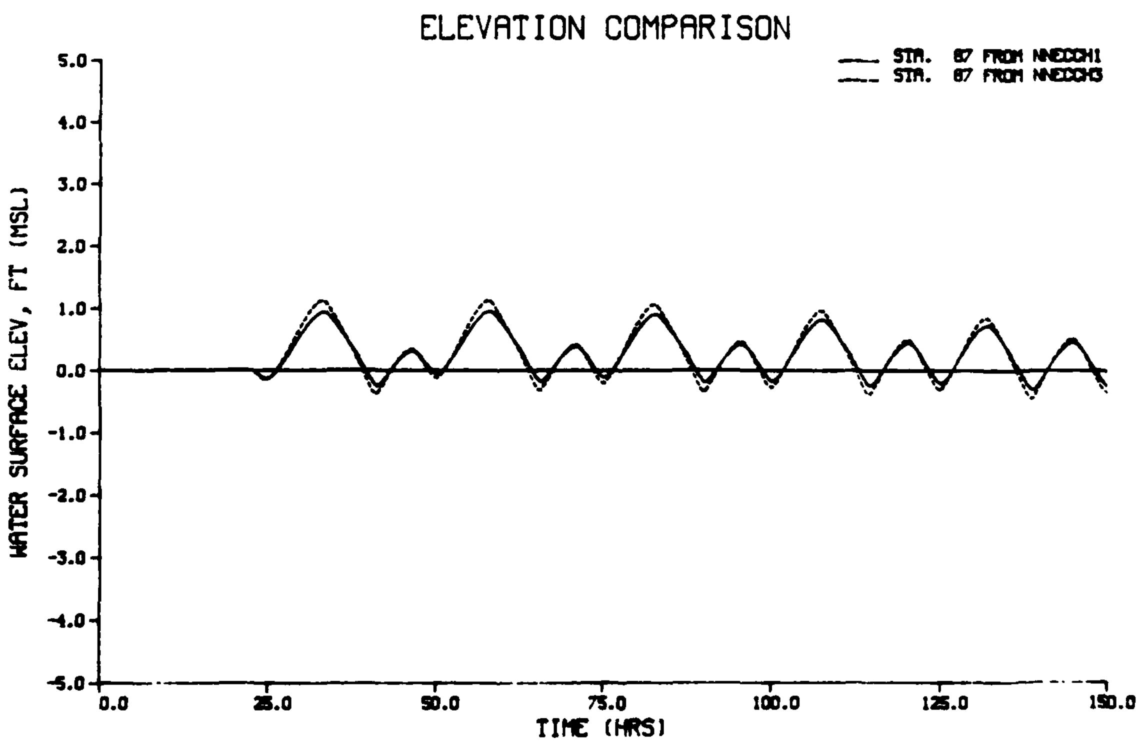


Figure 103. Effect of wetlands connection on tidal elevations, proposed muted tidal wetlands, non-navigable entrance and by-pass channel, NNECCH1 - wetlands not connected, NNECCH3 - wetlands connected

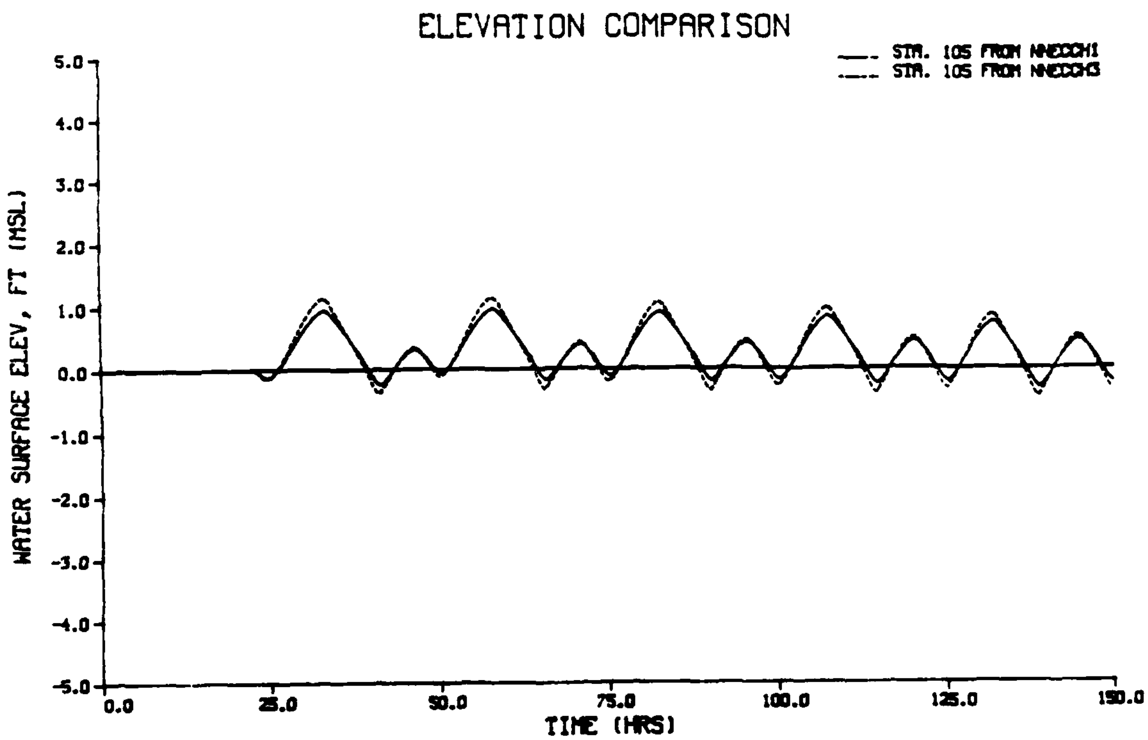


Figure 104. Effect of wetlands connection on tidal elevations, proposed muted tidal wetlands, non-navigable entrance and by-pass channel, NNECCH1 - wetlands not connected, NNECCH3 - wetlands connected

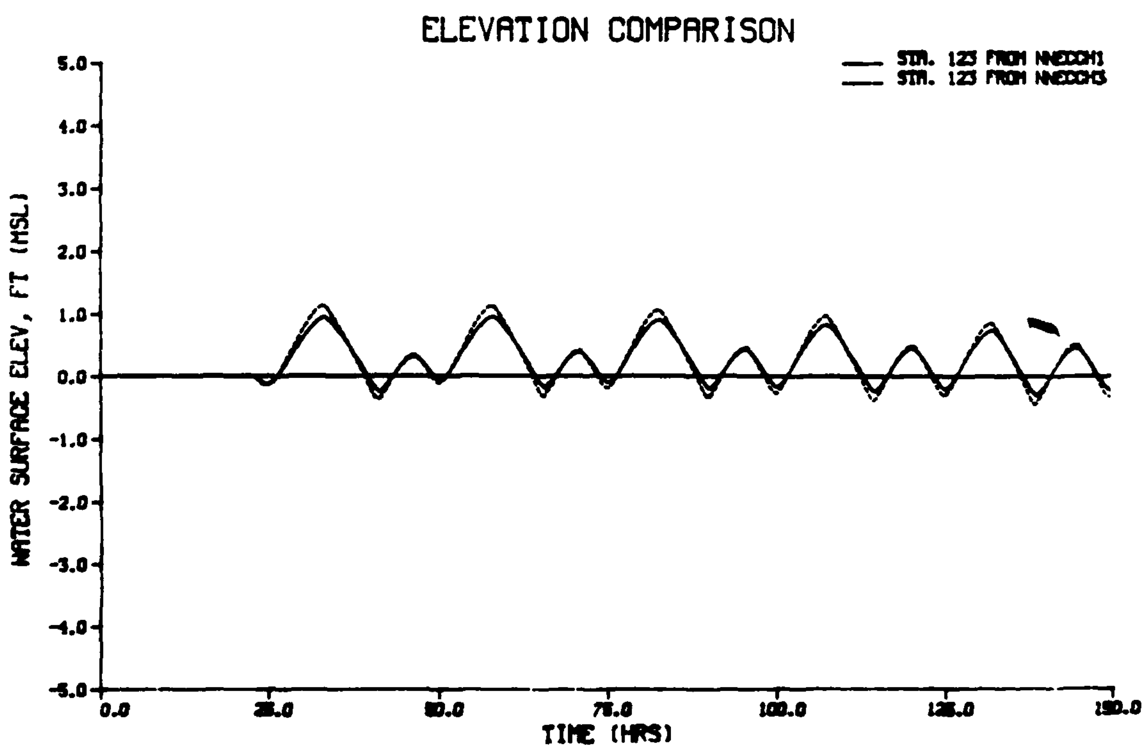


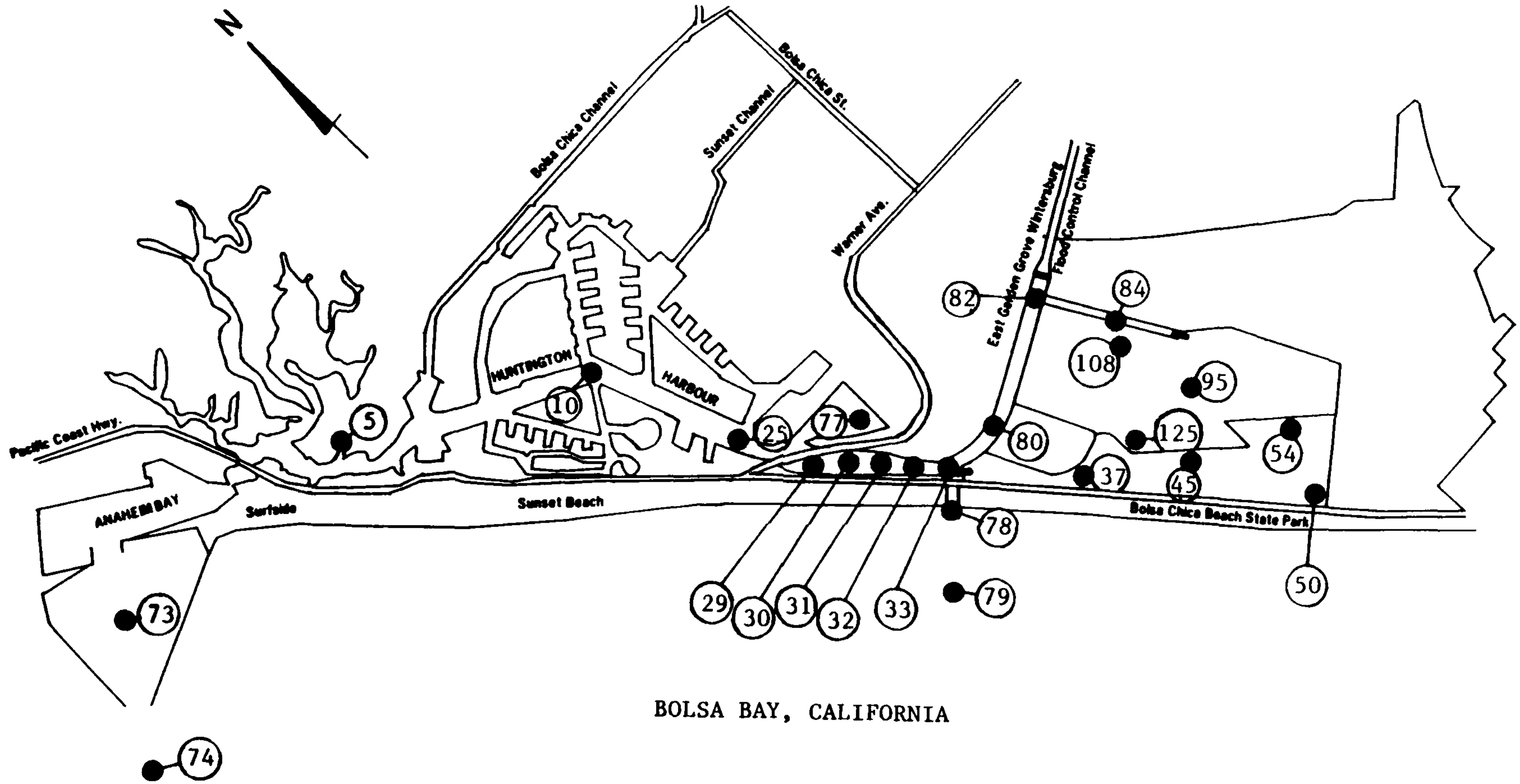
Figure 105. Effect of wetlands connection on tidal elevations, proposed muted tidal wetlands, non-navigable entrance and by-pass channel, NNECCH1 - wetlands not connected, NNECCH3 - wetlands connected

NNECC
Non-Navigable Entrance Channel and No By-Pass Connector Channel to Marina

153. The connector channel between the proposed new marina at Warner Avenue and the EGG-WFCC was conceived to reduce excessive velocities through Outer Bolsa Bay. It was believed that this channel would become quite significant should the non-navigable entrance channel close because of shoaling from littoral material in the surf zone. To determine the effects on tidal water surface time-histories and velocities in the vicinity of Outer Bolsa Bay, the hydrodynamic simulations were repeated under the assumption that the connector channel would not be installed.

Tidal elevations

154. Water surface elevations from simulations at pertinent nodes of interest are displayed in Appendix I. The effects of the concept of a non-navigable entrance channel with no by-pass connector channel to the marina on typically representative water surface time-histories are presented in Figures 107 through 110 for Huntington Harbour (Node 10), Outer Bolsa Bay (Node 32), Inner Bolsa Bay (Node 37), and the DFG muted tidal cell (Node 54), respectively. Time-histories of water surface elevations in the channel to the proposed muted tidal wetlands (Node 84), and in the proposed muted tidal wetlands (Node 95), are shown in Figures 111 and 112, respectively. Tidal ranges at representative locations throughout the bay system are presented in Table 10.



BOLSA BAY, CALIFORNIA

NNECC

Figure 106. Location of nodes for displaying water surface elevations under non-navigable entrance channel and no by-pass connector channel to marina conditions

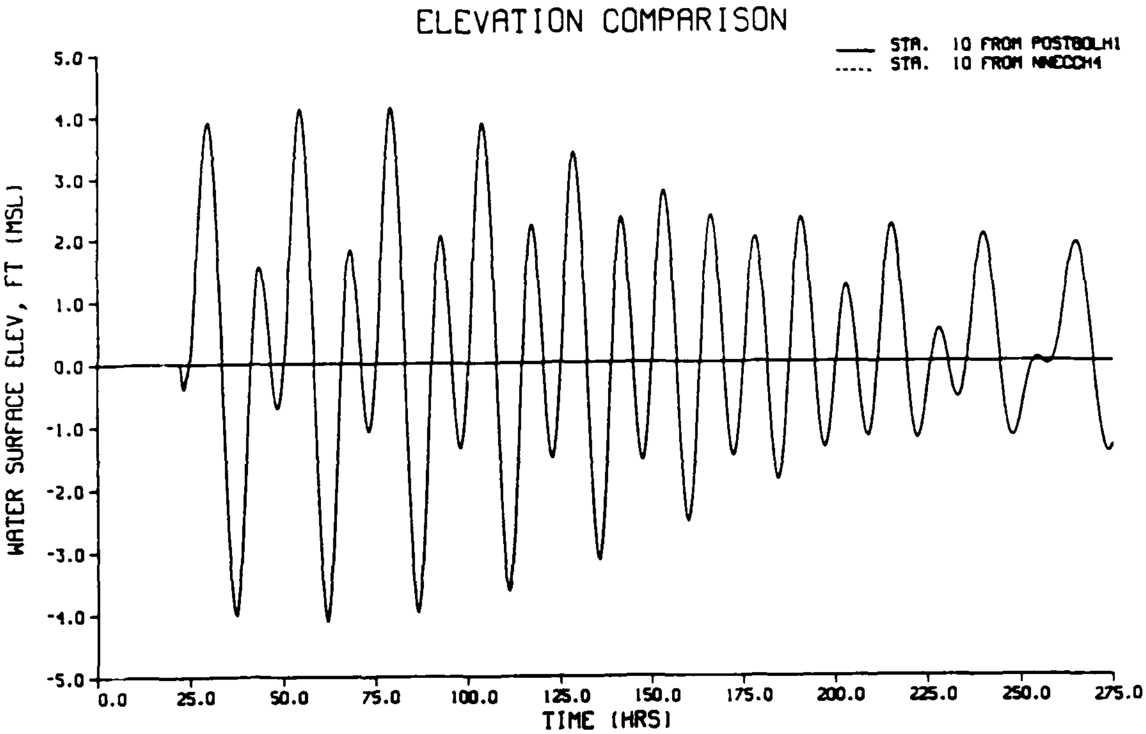


Figure 107. Tidal elevations in Huntington Harbour,
POSTBOL - existing condition
NNECCH4 - non-navigable entrance channel and no by-pass connector to marina

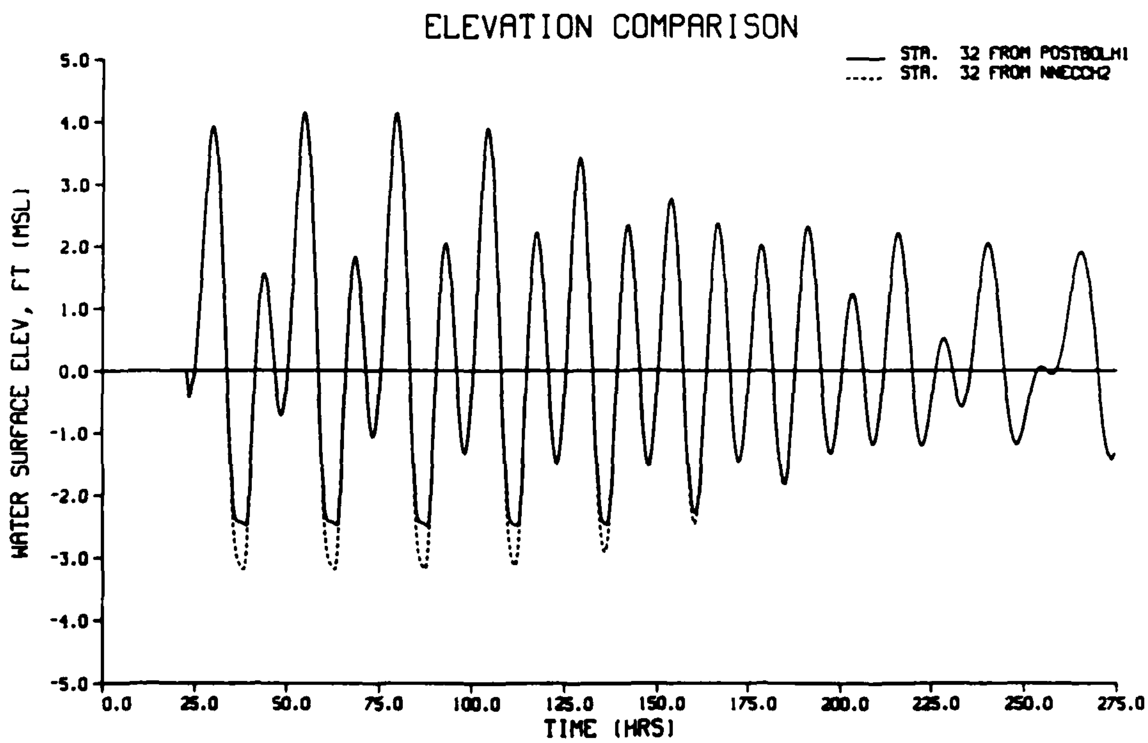


Figure 108. Tidal elevations in Outer Bolsa Bay,
POSTBOL - existing condition
NNECCH2 - non-navigable entrance channel and no by-pass connector to marina

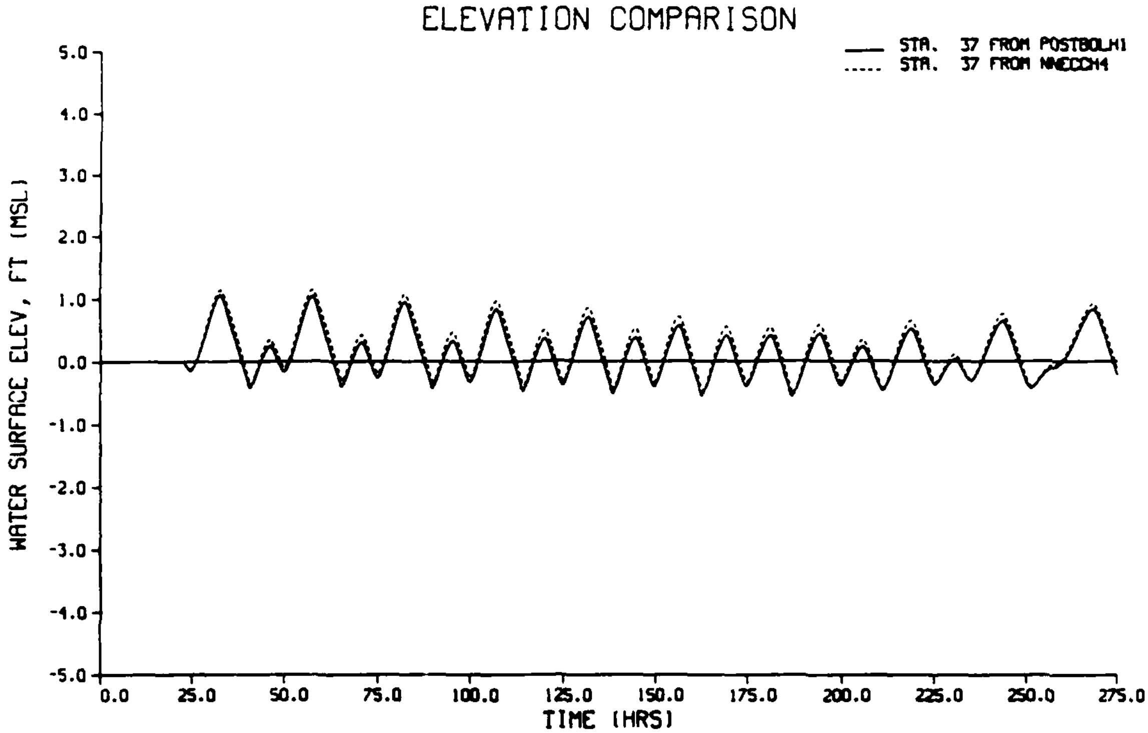


Figure 109. Tidal elevations in Inner Bolsa Bay,
POSTBOL - existing condition
NNECCH4 - non-navigable entrance channel and no by-pass connector to marina

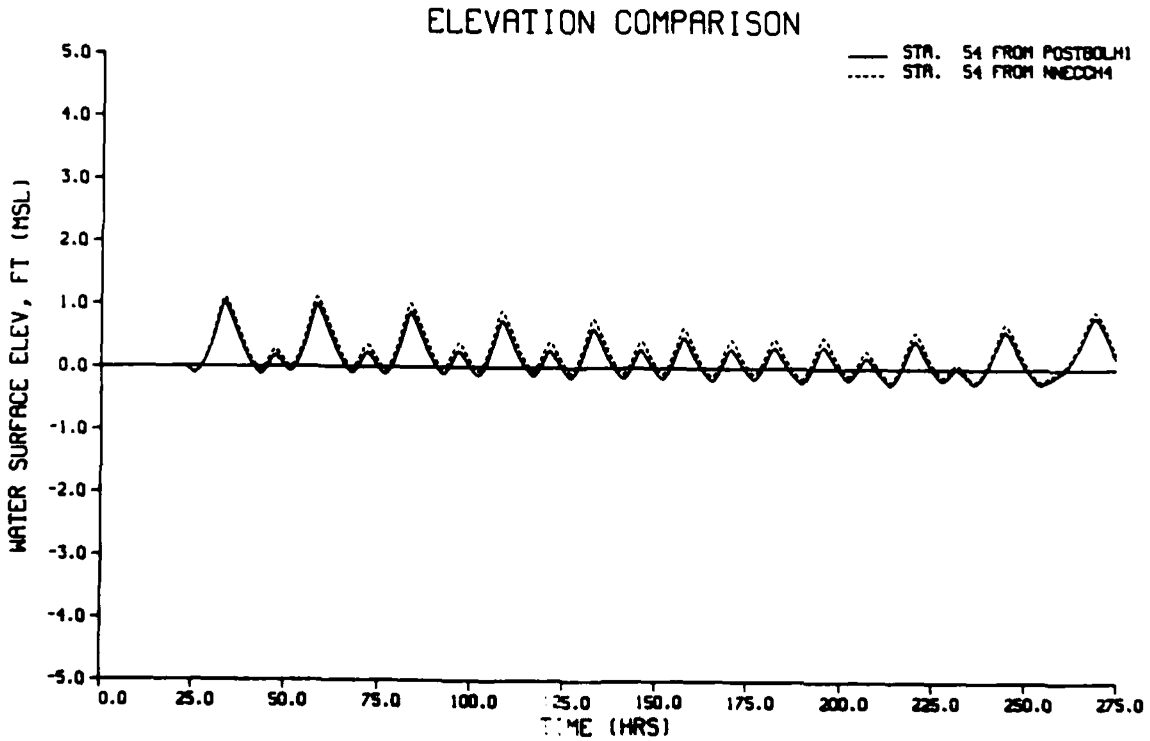


Figure 110. Tidal elevations in DFG muted tidal cell,
POSTBOL - existing condition
NNECCH4 - non-navigable entrance channel and no by-pass connector to marina

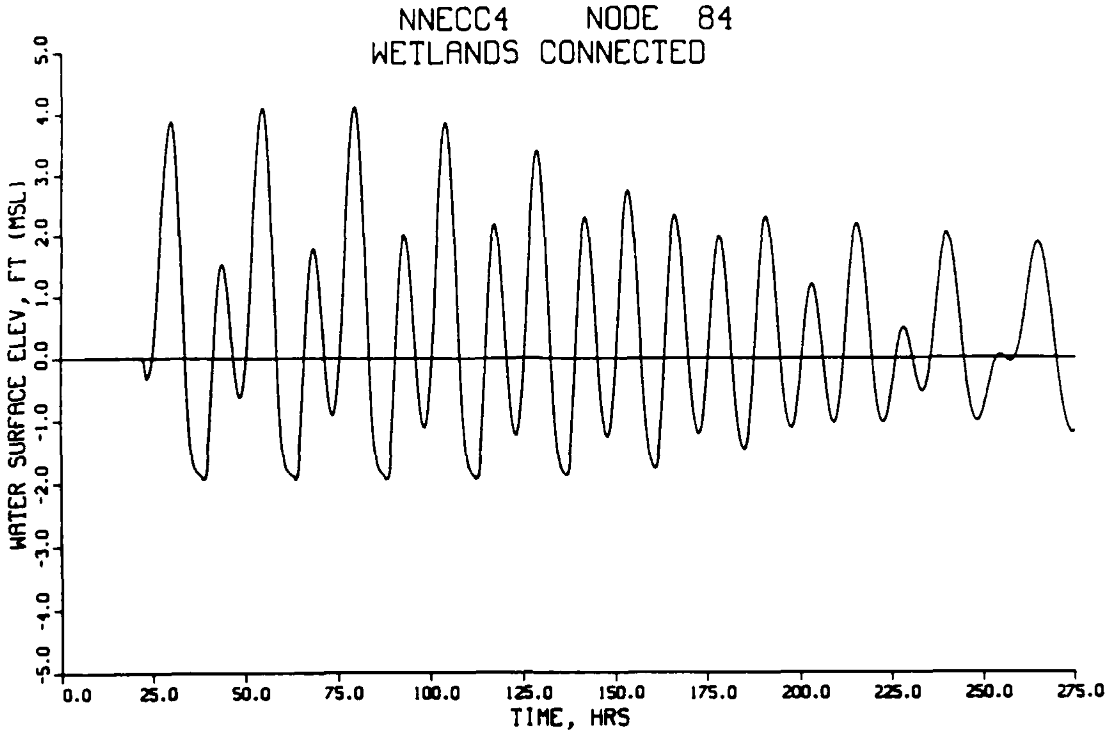


Figure 111. Tidal elevations in channel to proposed muted tidal wetlands under non-navigable entrance channel and no by-pass connector channel to proposed marina conditions, NNECCH4

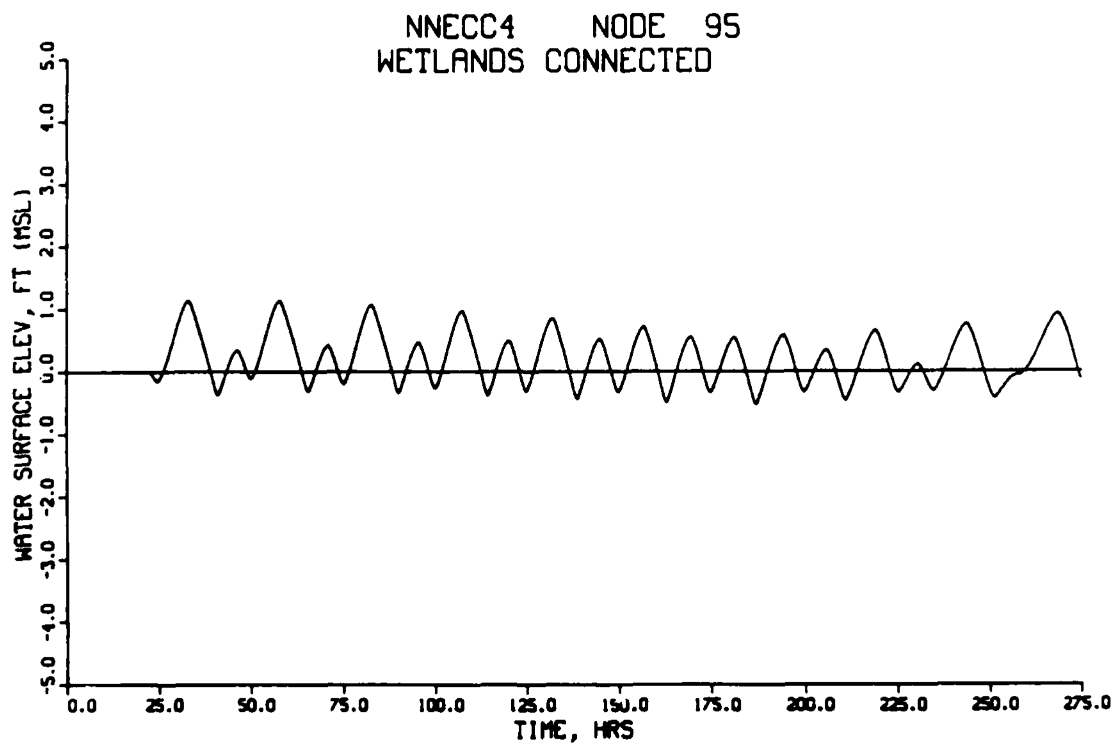


Figure 112. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance channel and no by-pass connector channel to proposed marina conditions, NNECCH4

Table 10

NNECC4
Non-Navigable Entrance Channel
and No By-Pass Connector Channel to Marina

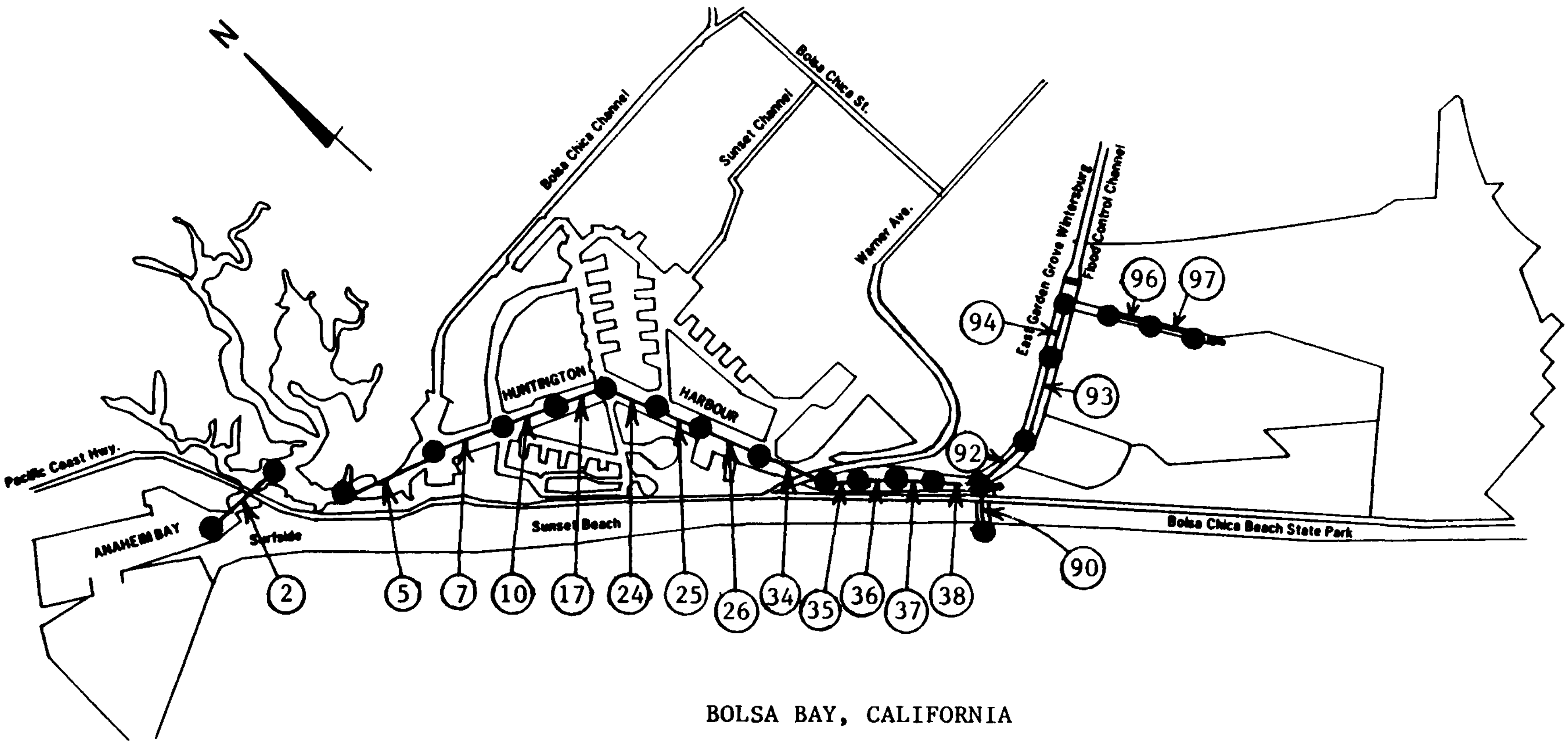
Wetlands Connected

Tide Ranges at Representatives Nodes

Location	Node No	High Tide feet, msl	Low Tide feet, msl
Huntington Harbour	10	4.10	-4.10
Outer Bolsa Bay	29	4.10	-4.10
Outer Bolsa Bay	30	4.10	-3.38
Outer Bolsa Bay	31	4.09	-3.26
Outer Bolsa Bay	32	4.09	-3.18
Outer Bolsa Bay	33	4.09	-2.87
Inner Bolsa Bay	37	1.14	-0.32
Inner Bolsa Bay	45	1.13	-0.29
Inner Bolsa Bay	50	1.14	-0.32
DFG muted tidal cell	54	1.10	-0.02
Proposed marina	77	4.10	-4.00
EGG-WFCC	82	4.09	-2.43
Channel to muted tidal wetlands	84	4.09	-1.94
Proposed muted tidal wetlands	95	1.14	-0.32
Proposed muted tidal wetlands	108	1.14	-0.32

Velocities

155. Average channel velocities at significant links of interest are presented in Appendix J. Maximum average channel velocities resulting from the non-navigable entrance channel concept with no by-pass connector channel to the proposed marina for all links along the main Huntington Harbour channel and Outer Bolsa Bay are presented in Table 11. The effects of this concept on typically representative average channel velocity time-histories are presented in Figures 114 through 119 for example displays in Huntington Harbour (Links 7, 17, and 26), at the location of the previous Warner Avenue bridge (Link 34), and in Outer Bolsa Bay (Links 36 and 38). Here, again, the



BOLSA BAY, CALIFORNIA

NNECC

Figure 113. Location of links for displaying average channel velocities under non-navigable entrance channel and no by-pass connector channel to marina conditions

Table 11

POSTBOL, Existing Condition
versus
NNECC4, Non-Navigable Entrance Channel
and No By-Pass Connector Channel to Marina

Wetlands Connected

Maximum Average Channel Velocities Along Main Channel System

Location	Link No	Maximum Average Channel Velocity ft per sec	
		POSTBOL	NNECC4
Pacific Coast Highway bridge	2	2.78	2.82
Huntington Harbour	5	1.42	1.53
Huntington Harbour	7	1.48	1.60
Huntington Harbour	10	0.71	0.79
Huntington Harbour	17	0.66	0.73
Huntington Harbour	24	0.57	0.66
Huntington Harbour	25	0.30	0.37
Huntington Harbour	26	0.34	0.45
Warner Avenue bridge	34	1.65	0.47
Outer Bolsa Bay	35	1.35	1.35
Outer Bolsa Bay	36	0.71	0.76
Outer Bolsa Bay	37	0.88	0.62
Outer Bolsa Bay	38	1.12	1.09
Non-navigable entrance channel	90	----	1.35
EGG-WFCC	94	----	0.53
Channel to muted tidal wetlands	97	----	1.39

velocities in Huntington Harbour are not exceedingly different from either existing conditions or the non-navigable entrance channel concept with a by-pass connector channel to the marina. Velocities are only slightly greater than existing conditions through the harbor, reflecting passage of the additional tidal prism required to fill and empty the proposed marina at Warner Avenue. Because this volume of tidal prism traverses Huntington Harbour, maximum average velocities in Outer Bolsa Bay for this concept do not exceed existing condition velocities. The by-pass connector channel to the marina is not needed to reduce maximum velocities in Outer Bolsa Bay.

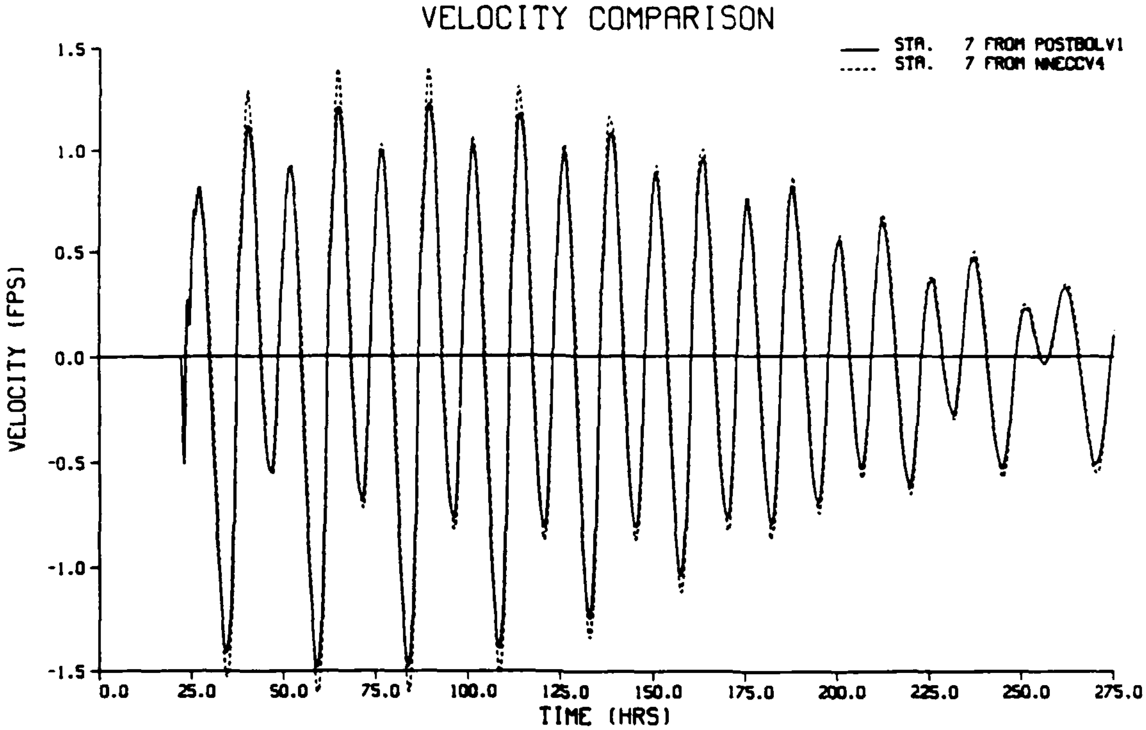


Figure 114. Average channel velocities in Huntington Harbour,
POSTBOL - existing condition
NNECCV4 - non-navigable entrance channel and no by-pass connector to marina

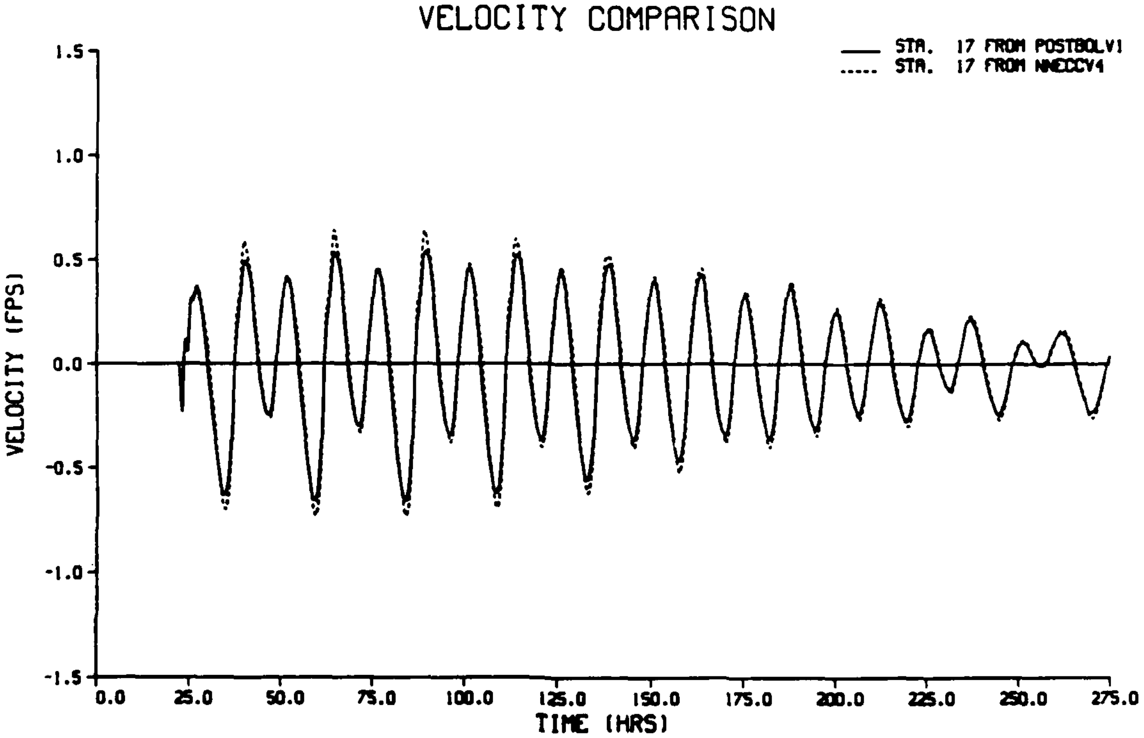


Figure 115. Average channel velocities in Huntington Harbour,
POSTBOL - existing condition
NNECCV4 - non-navigable entrance channel and no by-pass connector to marina

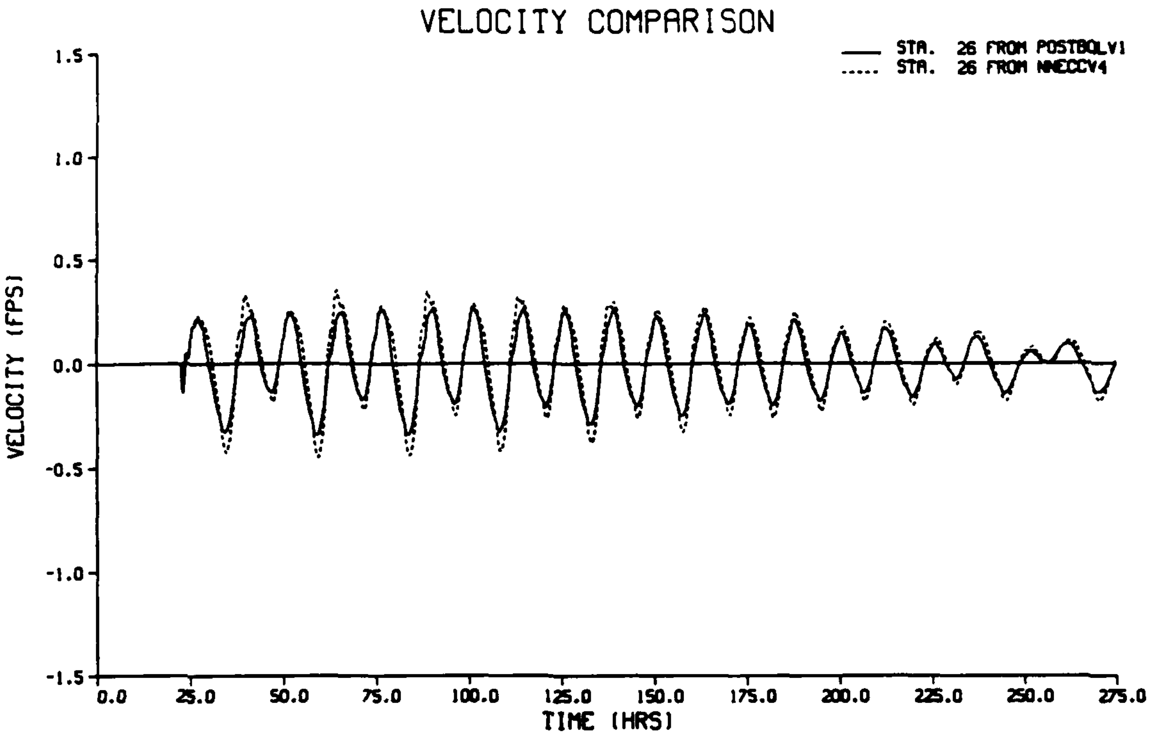


Figure 116. Average channel velocities in Huntington Harbour,
POSTBOL - existing condition
NNECCV4 - non-navigable entrance channel and no by-pass connector to marina

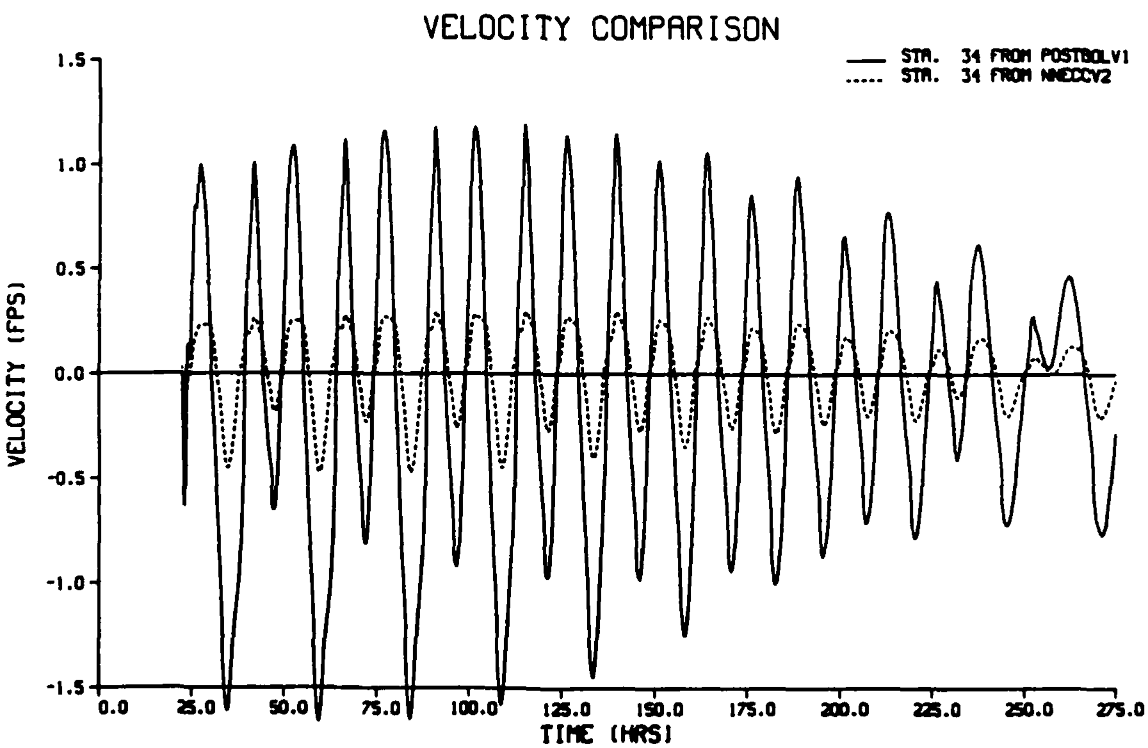


Figure 117. Average channel velocities at Warner Avenue bridge,
POSTBOL - existing condition
NNECCV2 - non-navigable entrance channel and no by-pass connector to marina

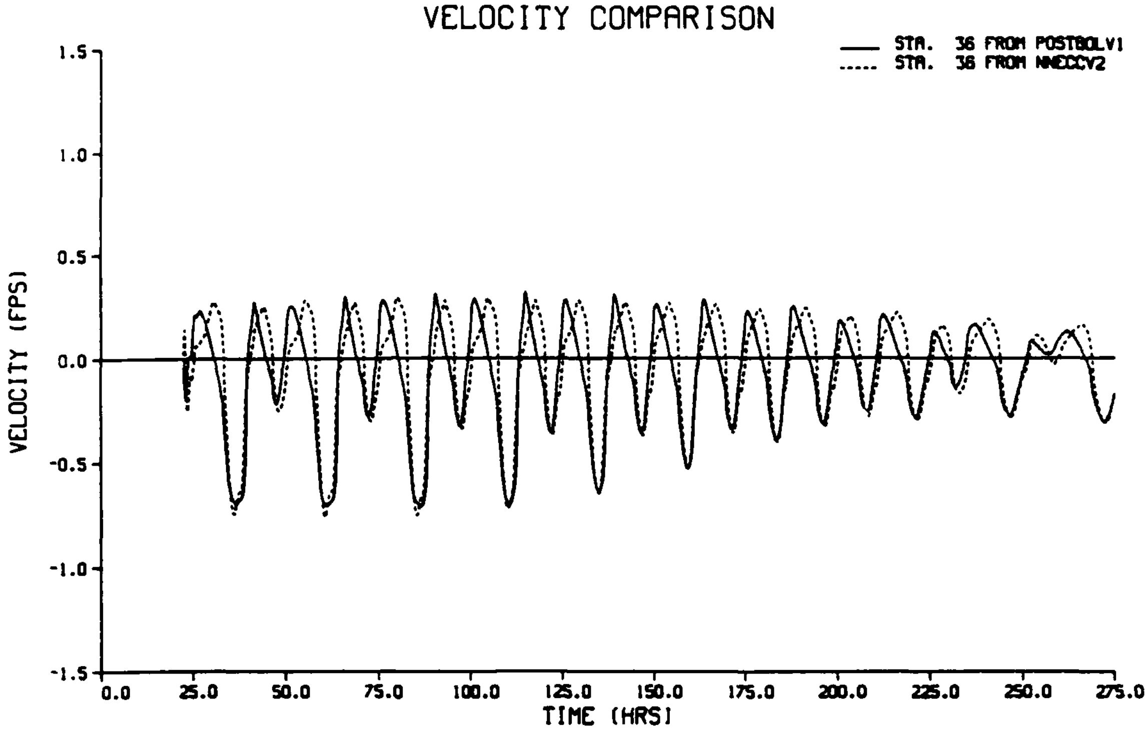


Figure 118. Average channel velocities in Outer Bolsa Bay,
POSTBOL - existing condition
NNECCV2 - non-navigable entrance channel and no by-pass connector to marina

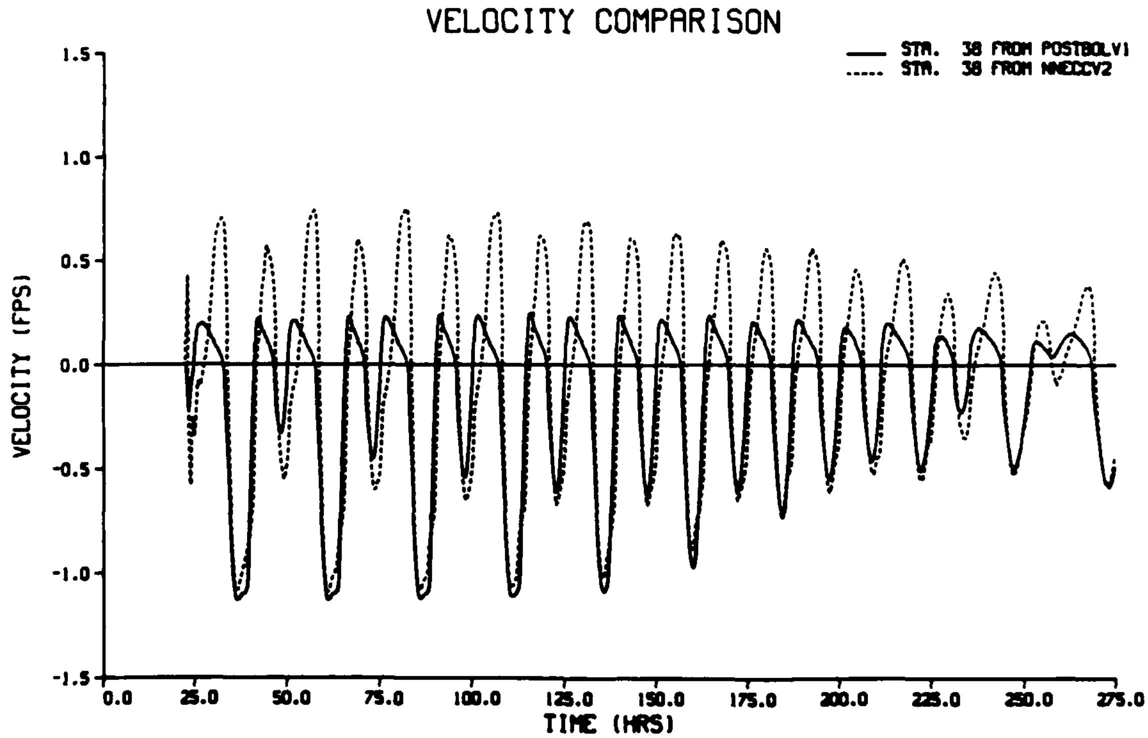


Figure 119. Average channel velocities in Outer Bolsa Bay,
POSTBOL - existing condition
NNECCV2 - non-navigable entrance channel and no by-pass connector to marina

Hydrodynamics of Outer Bolsa Bay with and without connector channel

156. The effects of a connector channel to the proposed marina on tidal elevations in Outer Bolsa Bay are shown in Figures 120 through 122. Here, high tide elevations are unaffected by the presence or absence of the connector channel, whereas low tide elevations fall slightly lower when the connector channel is installed in the numerical model. However, the magnitude of this lower tide elevation (0.2 to 0.3 ft at extreme low ocean tide regime) is small, and occurs within the channelized system of Outer Bolsa Bay.

157. Simultaneous effects on velocities in Outer Bolsa Bay are presented in Figures 123 through 127. Ebb velocities increase about 20 percent at the maximum ocean tide range, increasing at Node 35 from about 1.15 ft per sec when the connector channel is installed to about 1.4 ft per sec when the connector channel is removed. In either event, these velocities do not appear to be significant from the standpoint of eroding sediments from Outer Bolsa Bay if the non-navigable entrance channel remains open to tidal prism exchange with the ocean. Conversely, if the non-navigable entrance is permitted to close by littoral material, then velocities may increase in Outer Bolsa Bay, with or without the presence of the connector channel to the marina. This scenario will be subsequently analyzed.

Hydrodynamics of EGG-WFCC with and without connector channel

158. The EGG-WFCC is designed with a bottom elevation of -5 ft msl, and a bottom width of 250 ft. The connector channel from EGG-WFCC near the flood control tide gates to the proposed muted tidal wetlands has the same bottom elevation (-5 ft msl), but has a much narrower width (70 ft). Both of these channels are required to convey the same tidal prism to fill and empty the proposed muted tidal wetlands. Hence, the velocities in the connector channel to the proposed wetlands (up to 1.5 ft per sec) will be significantly greater than the velocities in EGG-WFCC (up to 0.7 ft per sec), although not of a magnitude to create an erosion problem. The differences created by whether the connector channel to the marina does or does not exist are very small.

159. While the water surface elevations in both channels rise to the same high tide line, the frictional resistance afforded by the channel boundaries retards the water surface under low tide conditions. This causes the water surface to remain at a higher elevation in the upper reaches of the EGG-WFCC and the connector channel to the muted tidal wetlands than in the

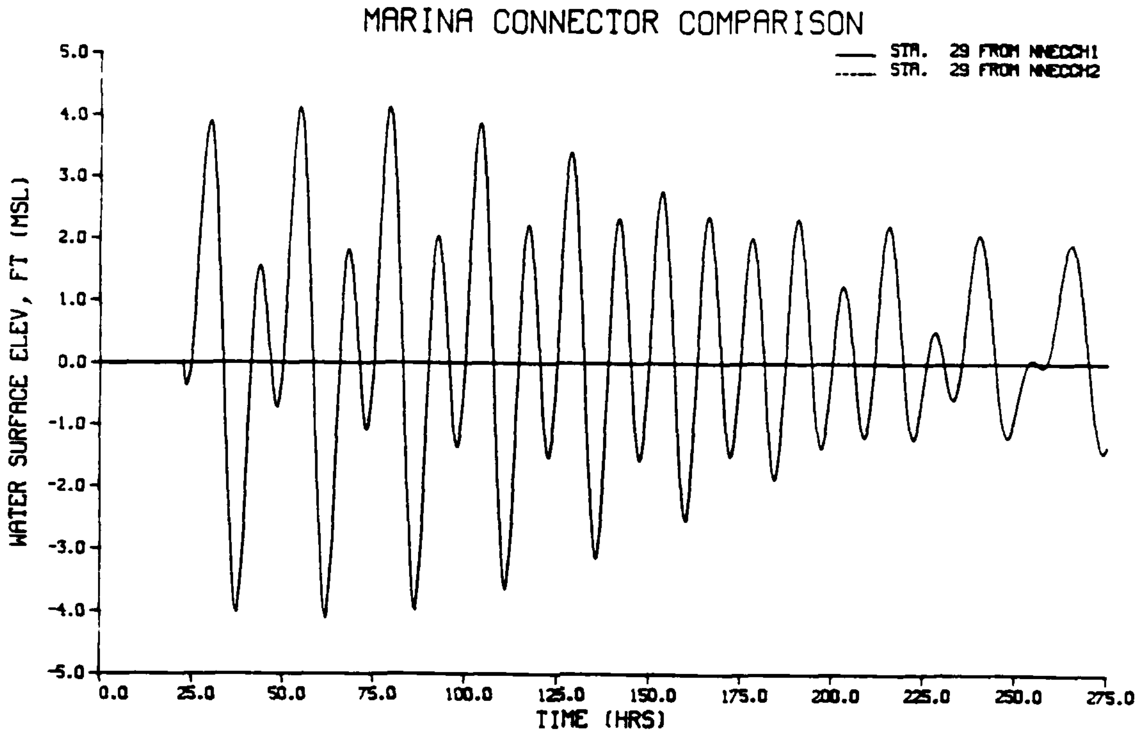


Figure 120. Effect of by-pass connector to marina on tidal elevations, Outer Bolsa Bay, non-navigable entrance channel, NNECCH1 - with by-pass connector, NNECCH2 - no by-pass connector

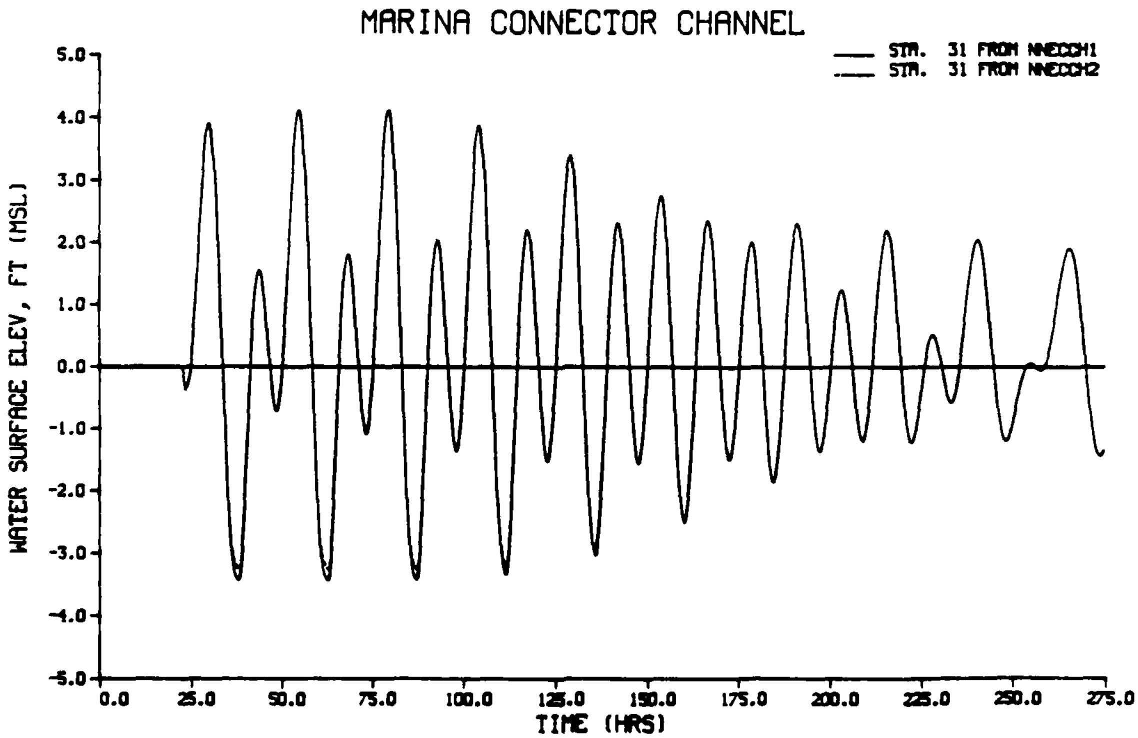


Figure 121. Effect of by-pass connector to marina on tidal elevations, Outer Bolsa Bay, non-navigable entrance channel, NNECCH1 - with by-pass connector, NNECCH2 - no by-pass connector

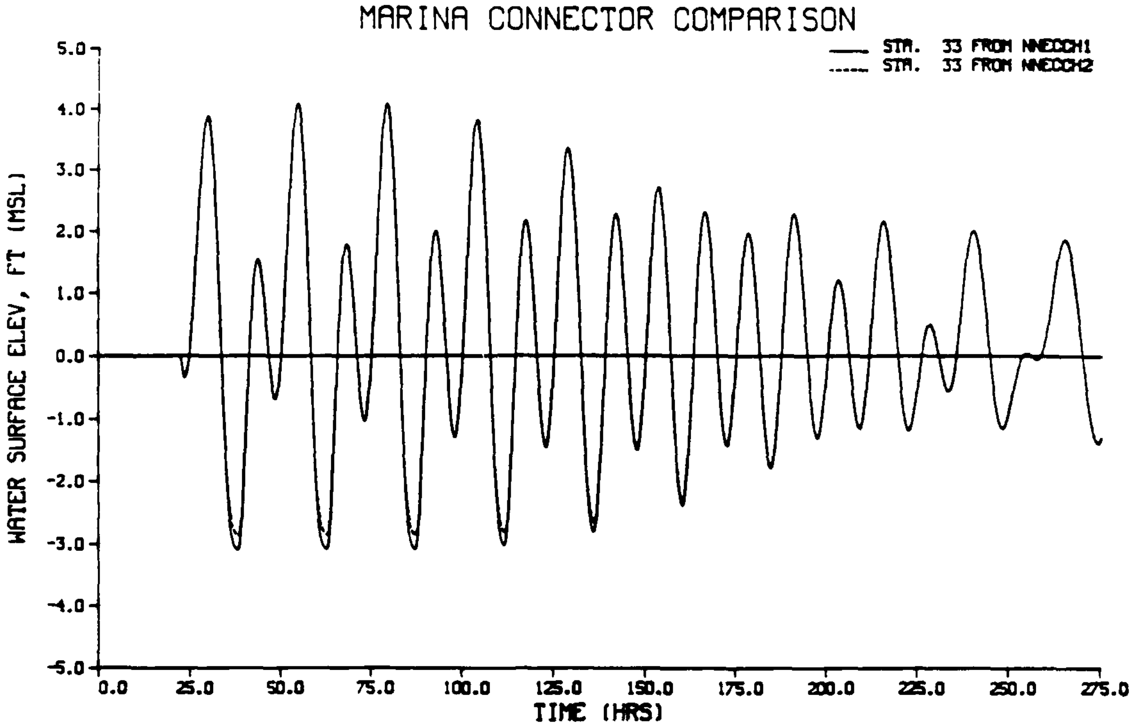


Figure 122. Effect of by-pass connector to marina on tidal elevations, Outer Bolsa Bay, non-navigable entrance channel, NNECCH1 - with by-pass connector, NNECCH2 - no by-pass connector

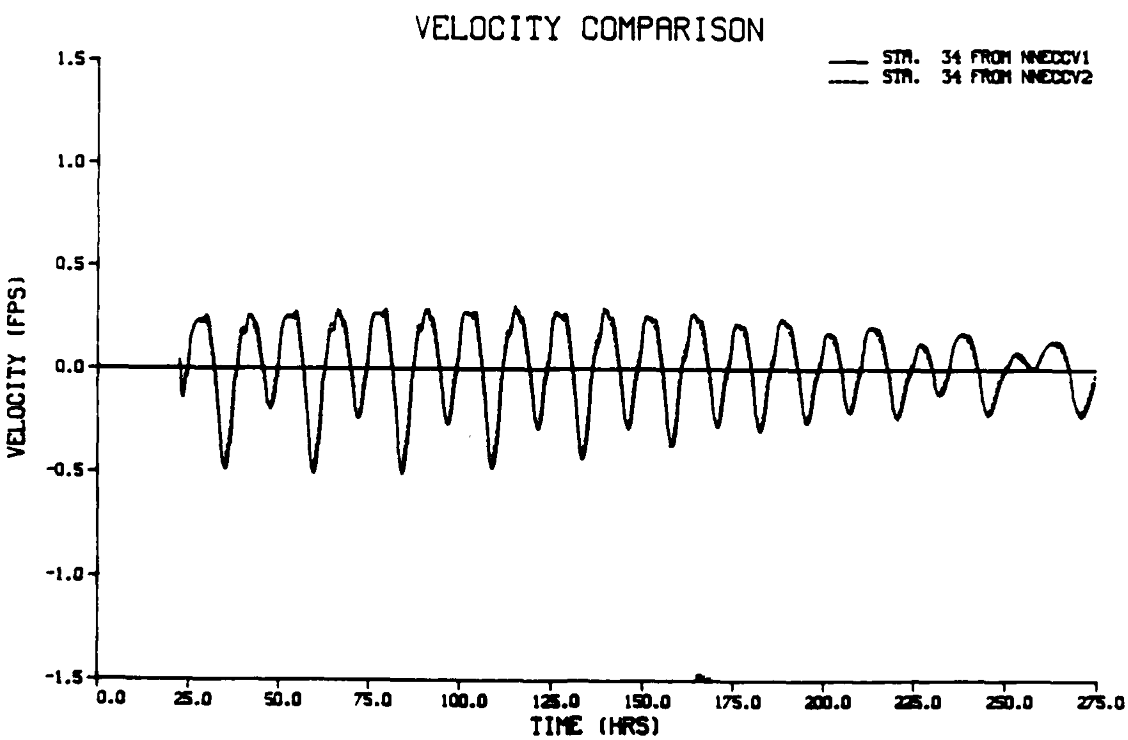


Figure 123. Effect of by-pass to marina on average channel velocities, Outer Bolsa Bay, non-navigable entrance channel, NNECCV1 - with by-pass connector, NNECCV2 - no by-pass connector

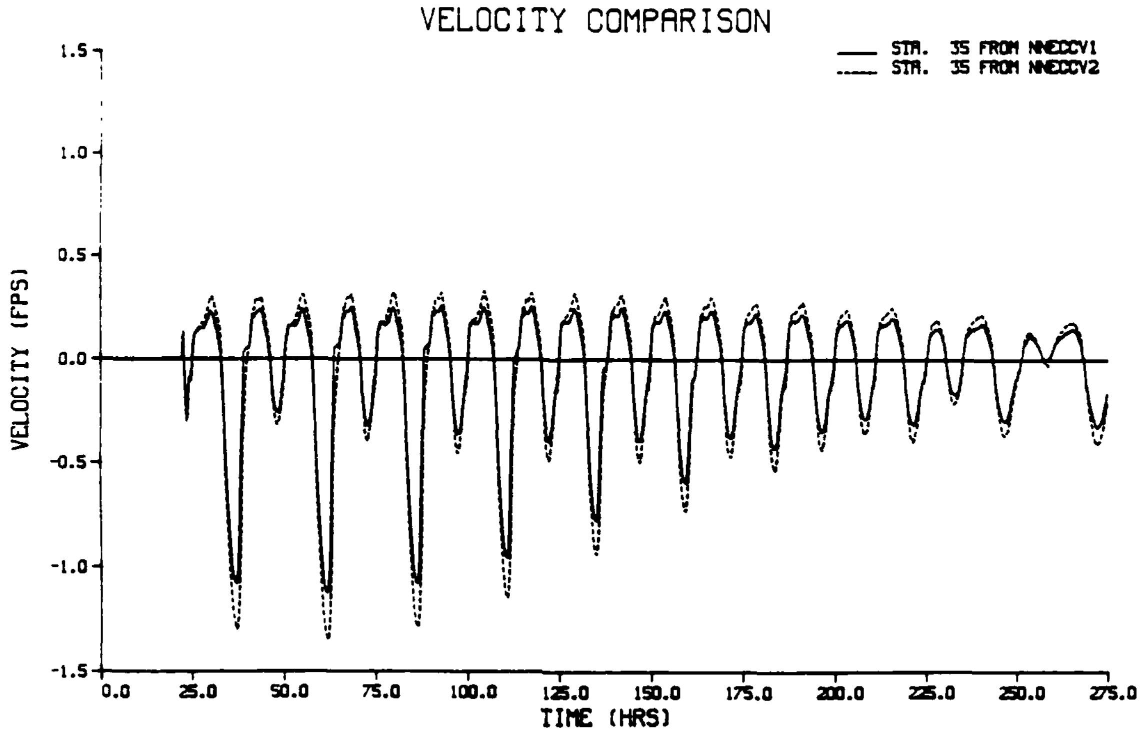


Figure 124. Effect of by-pass to marina on average channel velocities, Outer Bolsa Bay, non-navigable entrance channel, NNECCV1 - with by-pass connector, NNECCV2 - no by-pass connector

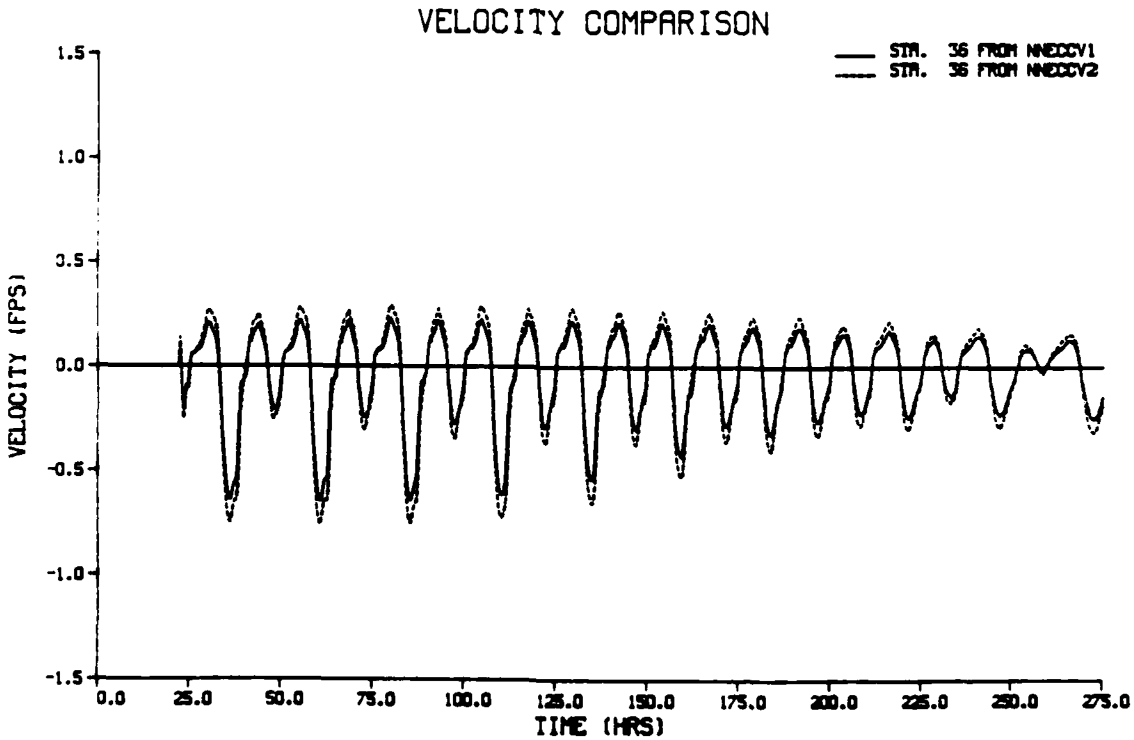


Figure 125. Effect of by-pass to marina on average channel velocities, Outer Bolsa Bay, non-navigable entrance channel, NNECCV1 - with by-pass connector, NNECCV2 - no by-pass connector

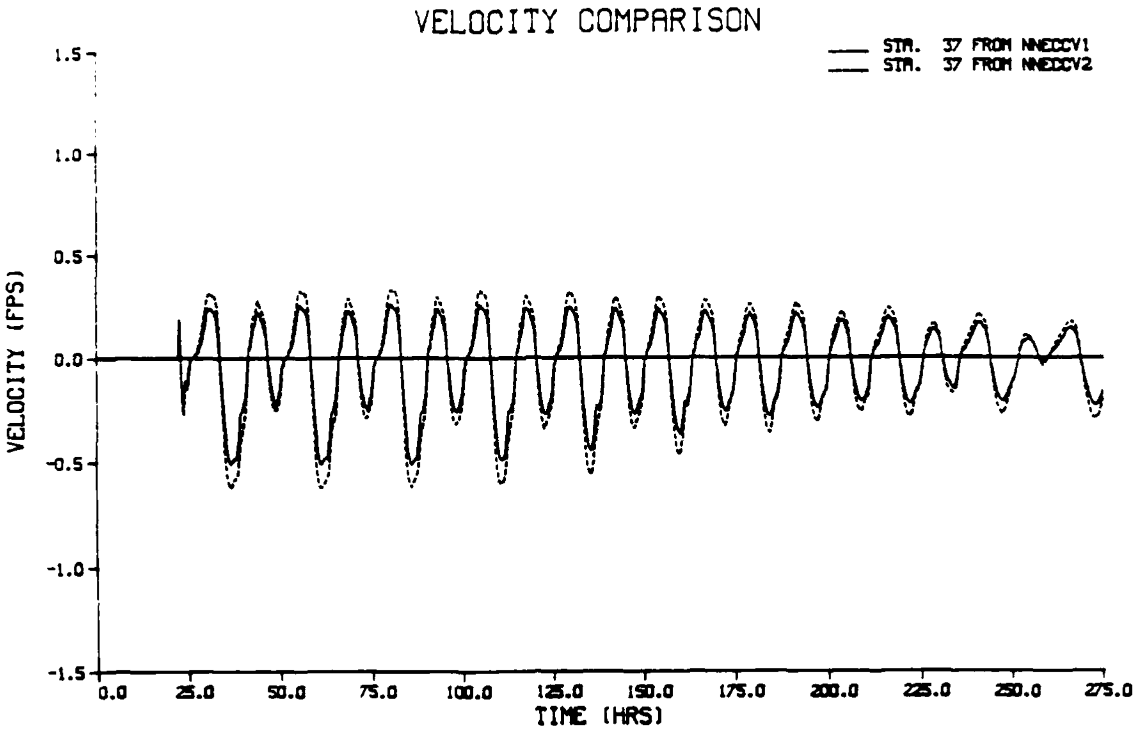


Figure 126. Effect of by-pass to marina on average channel velocities, Outer Bolsa Bay, non-navigable entrance channel, NNECCV1 - with by-pass connector, NNECCV2 - no by-pass connector

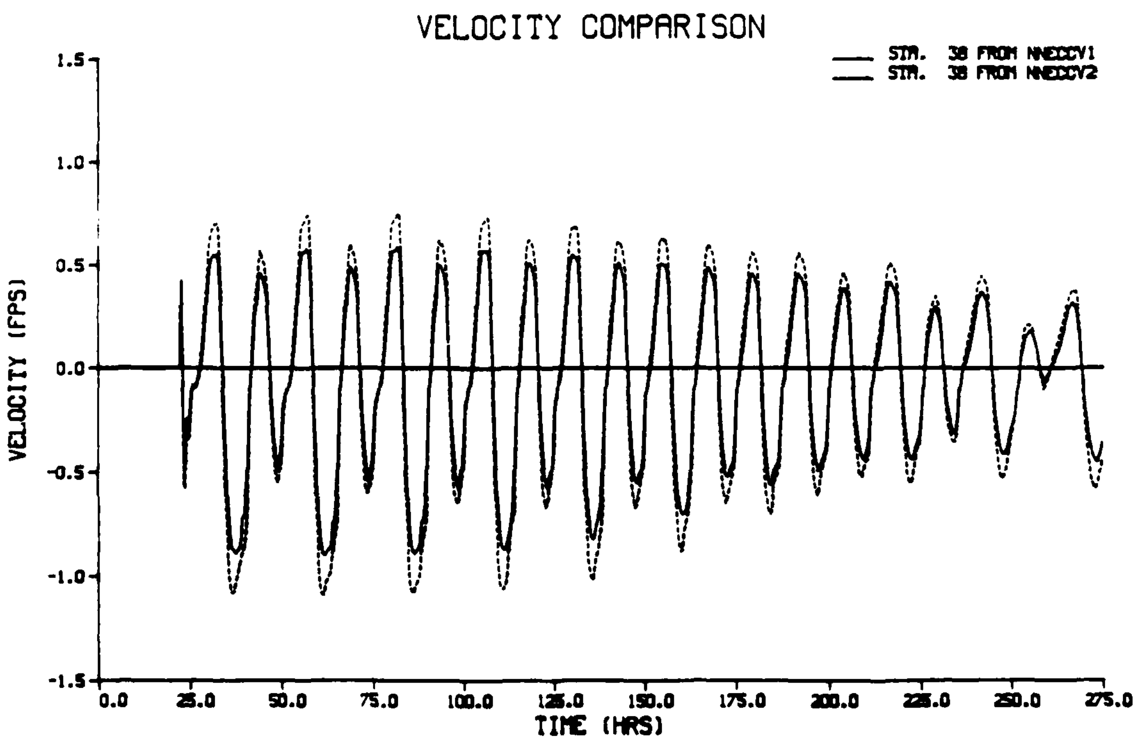


Figure 127. Effect of by-pass to marina on average channel velocities, Outer Bolsa Bay, non-navigable entrance channel, NNECCV1 - with by-pass connector, NNECCV2 - no by-pass connector

lower reaches of the EGG-WFCC and the ocean under low tide conditions. This phenomena is displayed for water surface time-histories in Figures 128 and 129 for nodes extending from the ocean to the upper extent of the connector channel to the proposed muted tidal wetlands.

160. The effects of a connector channel to the proposed new marina on velocities in the EGG-WFCC are shown in Figure 130, and on velocities in the connector channel to the proposed muted tidal wetlands is presented in Figure 131. Here it is observed that the effects of a connector channel to the marina do not affect velocities in either EGG-WFCC or the connector channel to the muted tidal wetlands. Velocity time-histories along the EGG and connector channel to the muted tidal wetlands are presented in Figure 132 for the scenario with a connector channel to the marina, and in Figure 133 where this connector channel to the marina is not installed in the numerical model. Here again, the differences between these two displays are found to be very small, based upon whether the connector channel to the marina does or does not exist.

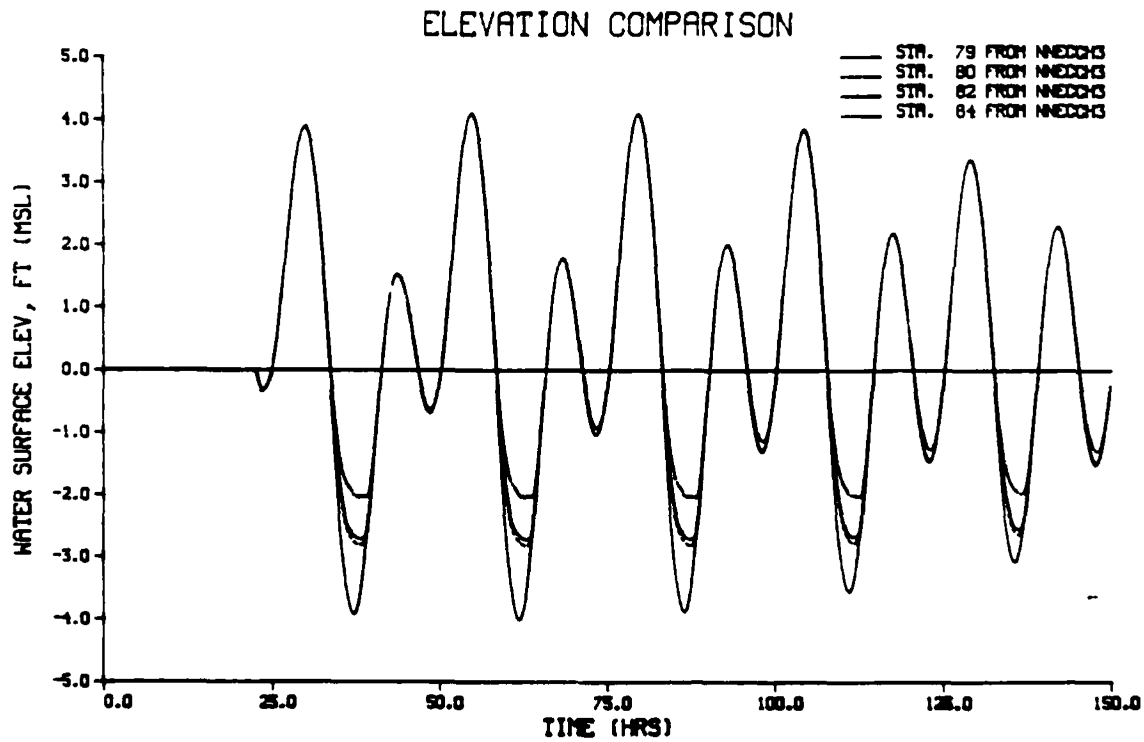


Figure 128. Water surface elevation profile from Pacific Ocean along EGG-WFCC and channel to proposed muted tidal wetlands, NNECCH3 - non-navigable entrance channel and by-pass connector to marina

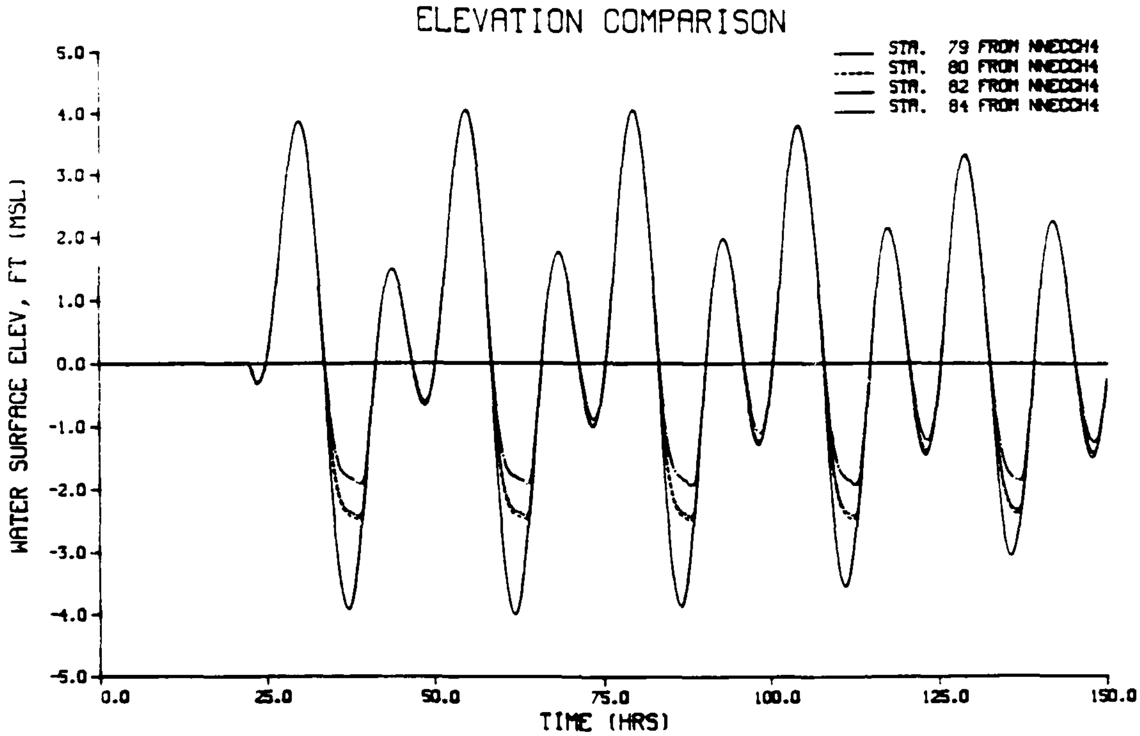


Figure 129. Water surface elevation profile from Pacific Ocean along EGG-WFCC and channel tp proposed muted tidal wetlands, NNECCH4 - non-navigable entrance channel and no by-pass connector to marina

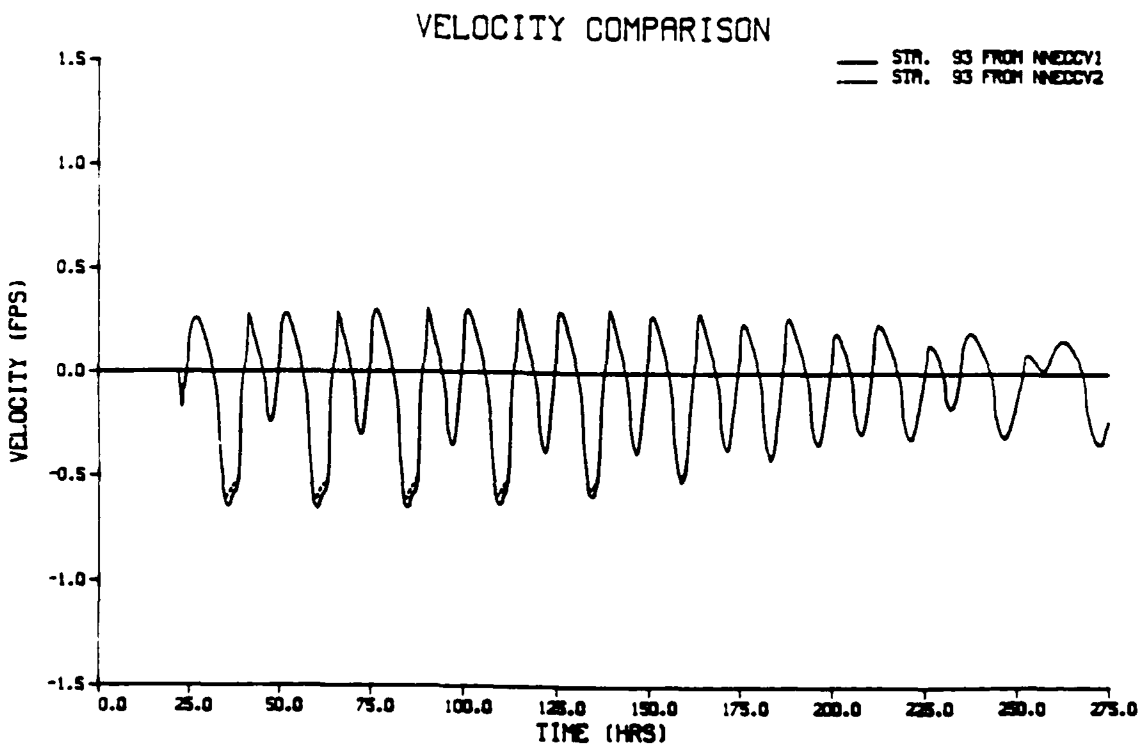


Figure 130. Effect of by-pass connector channel to marina on average channel velocities in EGG-WFCC, NNECCV1 - with by-pass connector, NNECCV2 - no by-pass connector

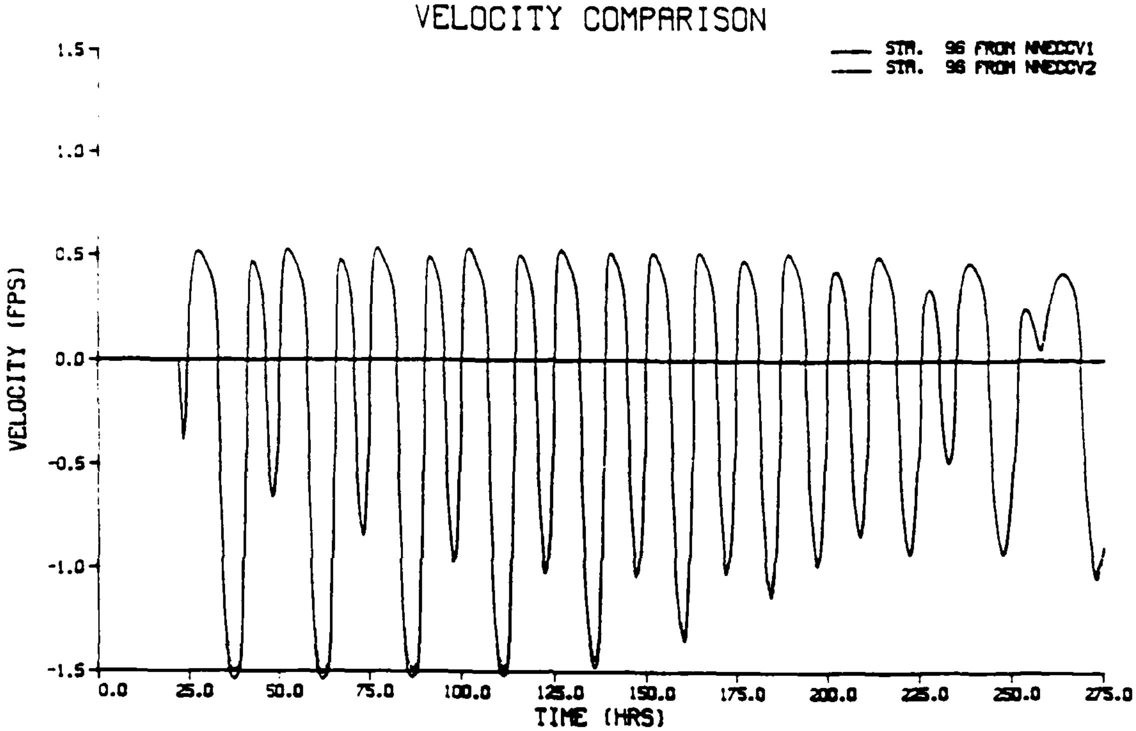


Figure 131. Effect of by-pass connector channel to marina on average channel velocities in channel to proposed muted tidal wetlands, NNECCV1 - with by-pass connector, NNECCV2 - no by-pass connector

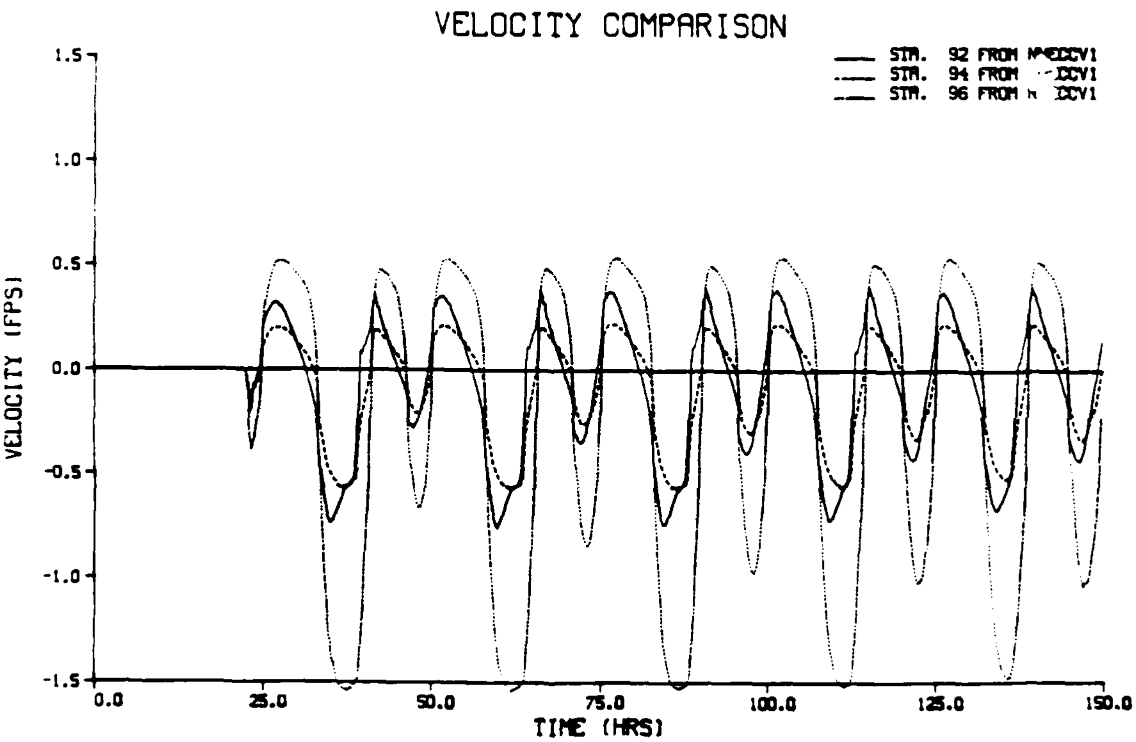


Figure 132. Average channel velocity profile along EGG-WFCC and channel to proposed muted tidal wetlands, NNECCV1 - non-navigable entrance channel and by-pass connector to marina

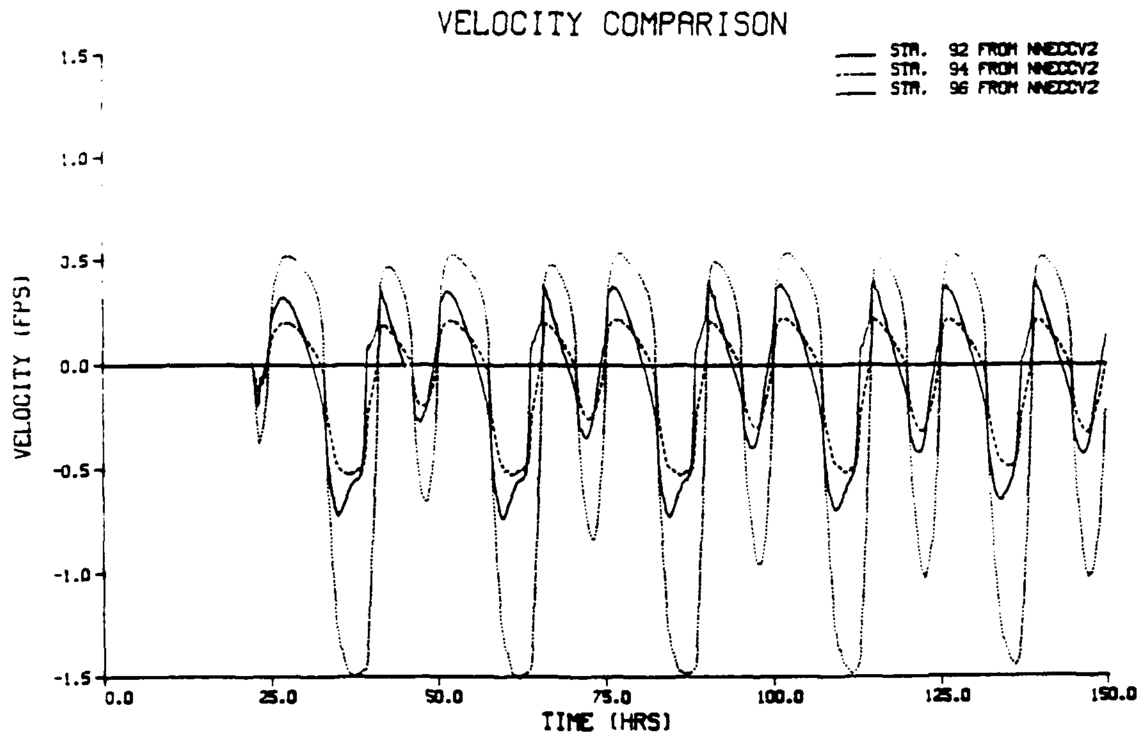


Figure 133. Average channel velocity profile along EGG-WFCC and channel to proposed muted tidal wetlands, NNECCV2 - non-navigable entrance channel and no by-pass connector to marina

PART VIII: NON-NAVIGABLE ENTRANCE CHANNEL CLOSED

161. Concern exists regarding whether the non-navigable entrance channel will remain open under the simultaneous influence of tidal velocities that try to keep the entrance open, and littoral material transport in the surf zone which attempts to close the entrance. Flood flows downs the EGG-WFCC channel may reopen the entrance if indeed it does tend to close. However, such flood flows are random occurrences and quite infrequent in this region. Because the entrance channel structures terminate at mean high water line (+1.9 ft msl), they provide no barrier to longshore moving sediment that will enter the channel on flood tide and may or may not be swept into the ocean on ebb flow.

162. Hughes (1988) performed an analysis of this issue which indicated that the present design entrance cross-sectional area is greater than the equilibrium cross-sectional area that might be expected. If the ocean entrance system and accompanying bay developments as proposed for the non-navigable alternative were to be constructed as presently configured, it should be expected that the entrance channel would immediately shoal by deposition of littoral sediment until a somewhat smaller equilibrium area is reached. A first estimate of the equilibrium area can be obtained by assuming the tidal prism remains constant. However, the total tidal prism stored in the lagoonal area is apportioned between two entrances, Anaheim and Bolsa Bay. Reducing the area of one entrance may significantly alter the system's flow characteristics, and thus change that portion of the tidal prism that is served by the non-navigable entrance.

163. Hughes (1988) concluded that it is difficult at this time to state whether the proposed non-navigable entrance will continue to shoal to the point of closure after reaching an equilibrium area compatible with observed prototype inlets. He recommended that during any final design phase a tidal circulation numerical modeling effort developed for analyzing this particular item of interest be conducted. That kind of analysis is presently beyond the scope of this investigation.

164. For purposes of this study, it will hence be assumed that the entrance channel could close by littoral material in the surf zone. All other aspects of the non-navigable entrance channel concept remain constant. It now

becomes necessary to ascertain the impacts of such closure on tidal elevations and velocities throughout the Huntington Harbour, Outer Bolsa Bay, Inner Bolsa Bay, and proposed new enhanced muted tidal wetlands area. The situation now is highly similar to existing conditions, with all tidal flow for supporting the wetlands passing through Huntington Harbour and Outer Bolsa Bay. Because the tidal prism will have significantly increased over existing conditions, it may be expected that average channel velocities will accordingly increase in these regions.

NOENT
Non-Navigable Entrance Channel Closed and No By-Pass Connector Channel to Marina

Tidal elevations

165. The locations of all nodes pertinent to this analysis have previously been shown on Figure 106 (non-navigable entrance channel and no by-pass connector channel to marina concept). Tidal elevation time-histories covering the regions of interest are presented in Appendix K. Here, as in the existing condition data displays (both field measurements and simulations), low water elevations in Outer Bolsa Bay do not fall below -2.0 to -2.5 ft msl even though the tide in Huntington Harbour falls to -4.0 ft msl at extreme low tide range.

166. The effects of the concept of a closed non-navigable entrance with no by-pass connector channel to the marina on typical representative water surface time-histories are presented in Figures 134 through 137 for Huntington Harbour (Node 10), Outer Bolsa Bay (Node 32), Inner Bolsa Bay (Node 37), and the DFG muted tidal cell (Node 54), respectively. Time-histories of water surface elevations in the channel to the proposed muted tidal wetlands (Node 84), and in the proposed muted tidal wetlands (Node 95), are shown in Figures 138 and 139, respectively. Tidal ranges at representative locations throughout the bay system are presented in Table 12.

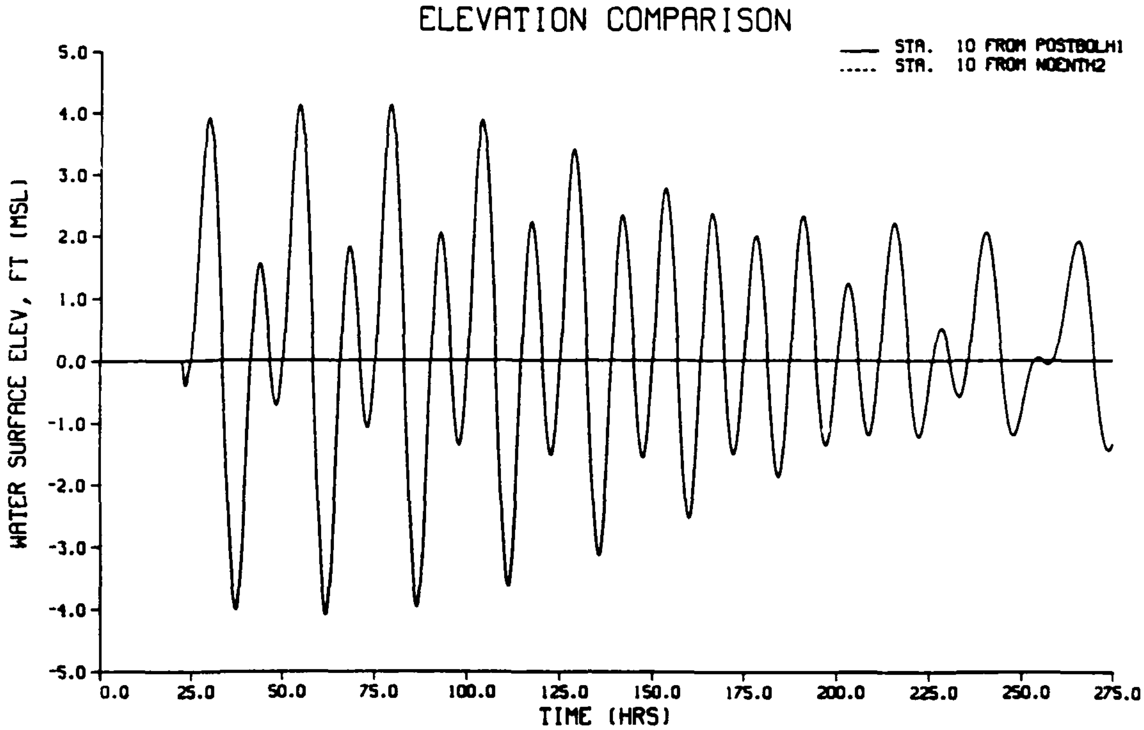


Figure 134. Tidal elevations in Huntington Harbour,
POSTBOL - existing condition
NOENTH2 - entrance channel closed and no by-pass connector to marina

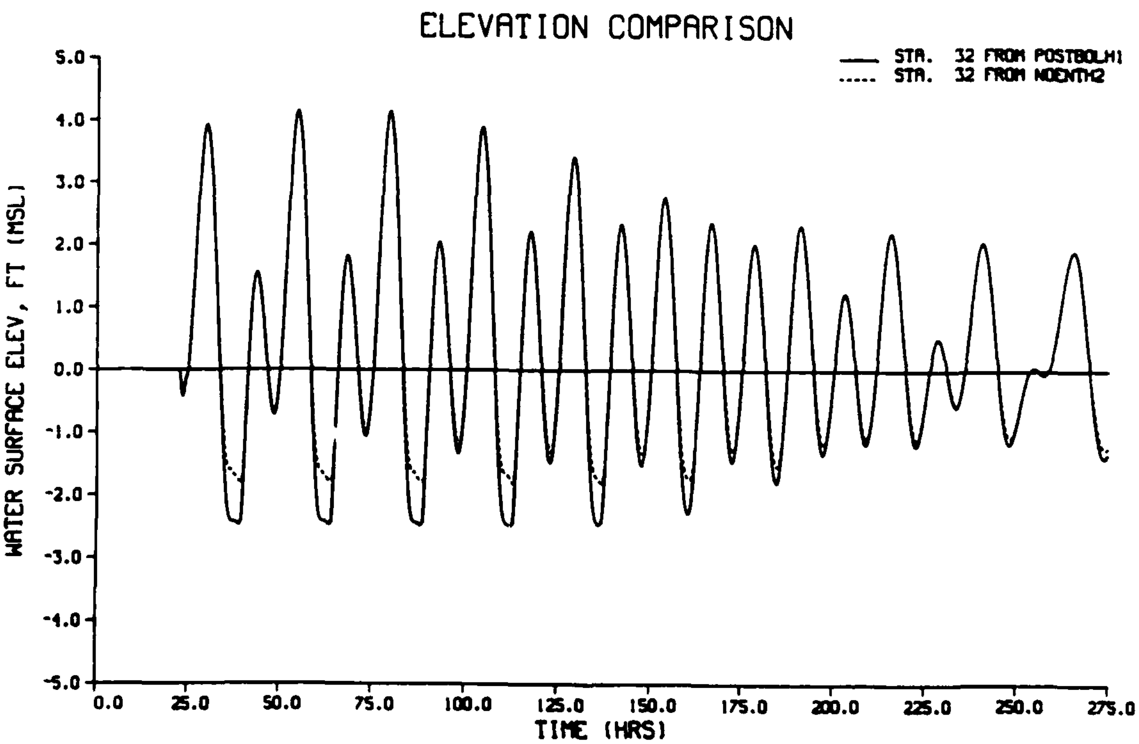


Figure 135. Tidal elevations in Outer Bolsa Bay,
POSTBOL - existing condition
NOENTH2 - entrance channel closed and no by-pass connector to marina

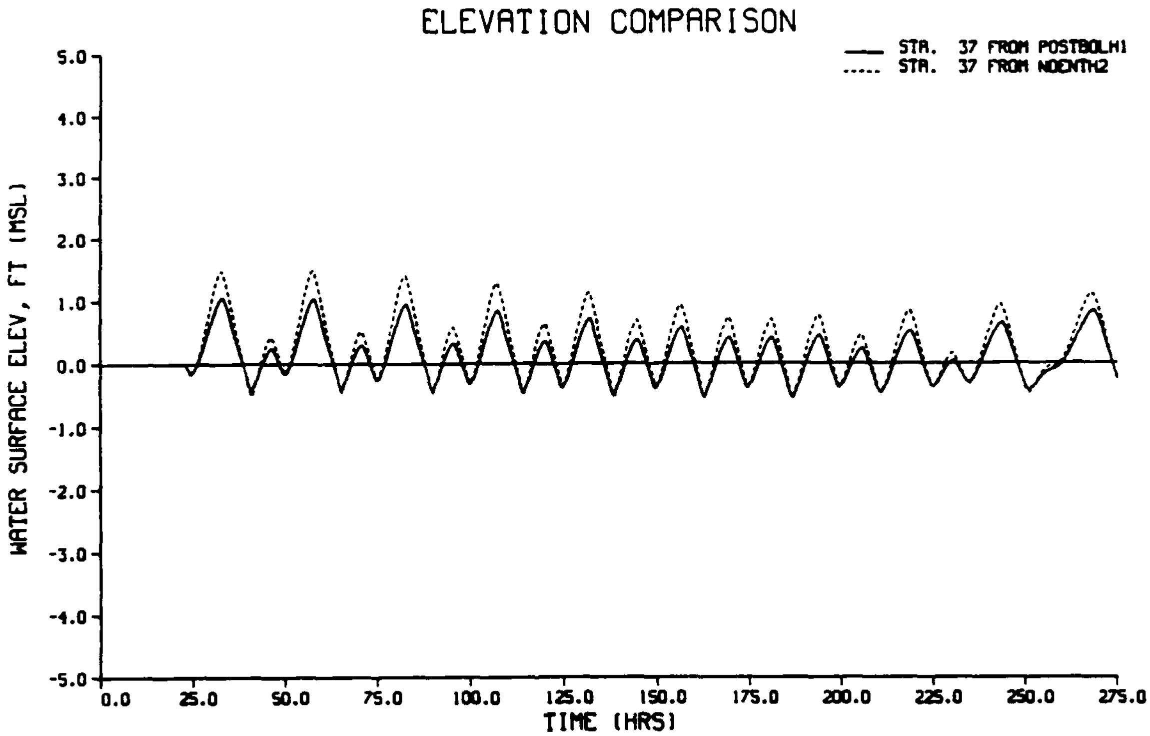


Figure 136. Tidal elevations in Inner Bolsa Bay,
POSTBOL - existing condition
NOENTH2 - entrance channel closed and no by-pass connector to marina

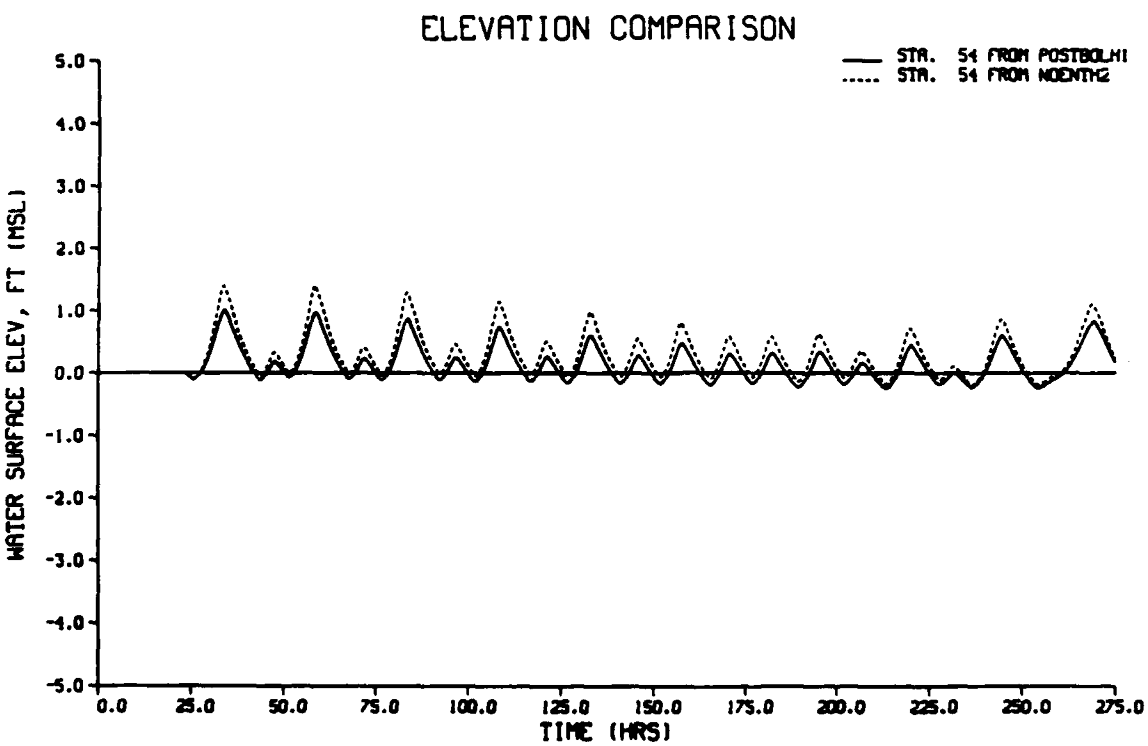


Figure 137. Tidal elevations in DFG muted tidal cell,
POSTBOL - existing condition
NOENTH2 - entrance channel closed and no by-pass connector to marina

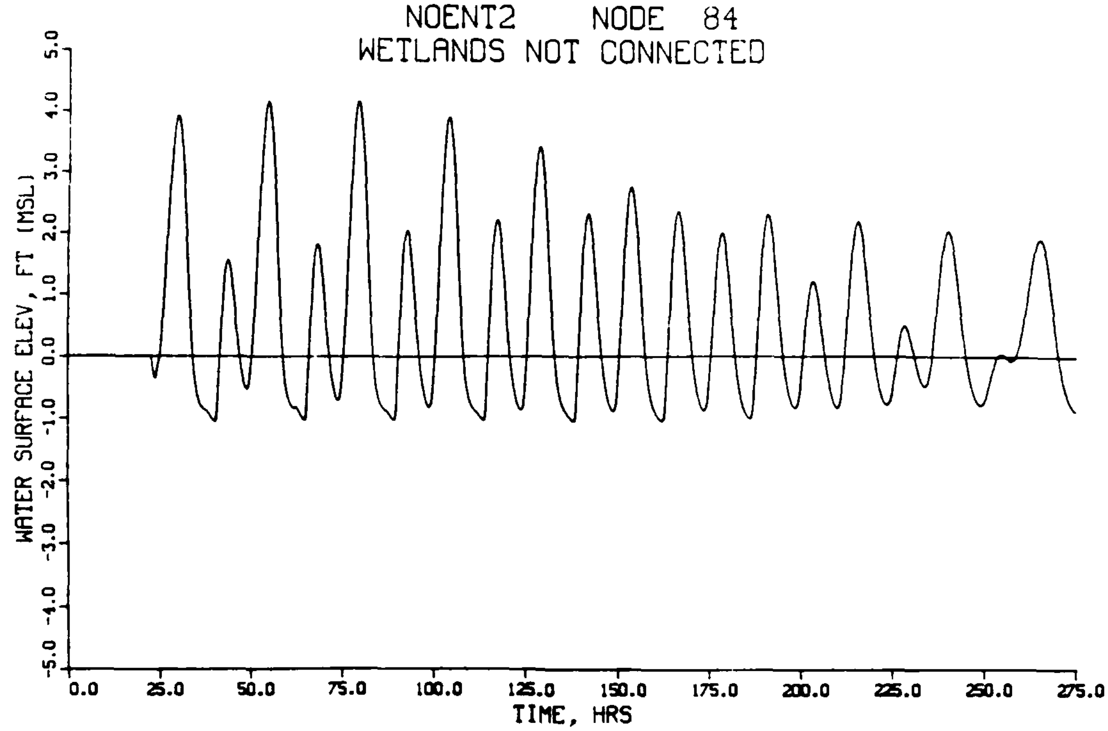


Figure 138. Tidal elevations in channel to proposed muted tidal wetlands under entrance channel closed and no by-pass connector channel to proposed marina conditions, NOENTH2

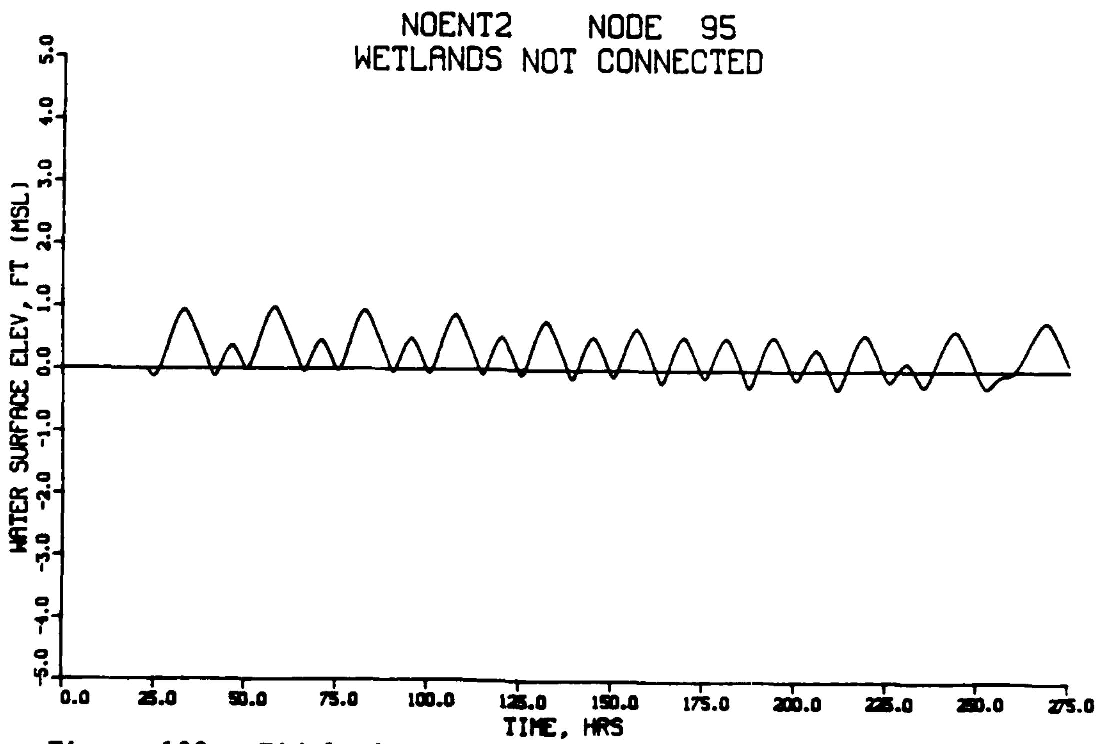


Figure 139. Tidal elevations in proposed muted tidal wetlands under entrance channel closed and no by-pass connector channel to proposed marina conditions, NOENTH2

Table 12

NOENT2

Non-Navigable Entrance Channel Closed
and No By-Pass Connector Channel to Marina

Wetlands Not Connected

Tide Ranges at Representatives Nodes

Location	Node No	High Tide feet, msl	Low Tide feet, msl
Huntington Harbour	10	4.10	-4.10
Outer Bolsa Bay	29	4.10	-4.00
Outer Bolsa Bay	30	4.10	-2.24
Outer Bolsa Bay	31	4.09	-2.06
Outer Bolsa Bay	32	4.09	-1.78
Outer Bolsa Bay	33	4.09	-1.18
Inner Bolsa Bay	37	1.49	-0.37
Inner Bolsa Bay	45	1.48	-0.37
Inner Bolsa Bay	50	1.49	-0.38
DFG muted tidal cell	54	1.41	-0.01
Proposed marina	77	4.10	-4.03
EGG-WFCC	82	4.09	-1.16
Channel to muted tidal wetlands	84	4.09	-1.03
Proposed muted tidal wetlands	95	0.99	-0.04
Proposed muted tidal wetlands	108	0.99	-0.04

Velocities

167. Links believed to be pertinent to the investigation have been shown previously on Figure 113 (non-navigable entrance channel and no by-pass connector channel to marina concept). Average channel velocities at the links of interest are presented in Appendix L. Maximum average channel velocities resulting from the closed non-navigable entrance channel concept with no by-pass connector channel to the proposed marina for all links along the main Huntington Harbour channel and Outer Bolsa Bay are compared with existing condition velocities in Table 13. The effects of this concept on typically representative average channel velocity time-histories are presented in

Figures 140 through 145 for example displays in Huntington Harbour (Links 7, 17, and 26), at the location of the previous Warner Avenue bridge (Link 34), and in Outer Bolsa Bay (Links 36 and 38).

168. Velocities in Huntington Harbour experience about a 21 percent increase in magnitude. A portion of this increase is due to filling and emptying the proposed marina. Since the entire tidal prism for the proposed enhanced muted tidal wetlands must pass through Outer Bolsa Bay, the increase in velocity in this region of up to 60 percent (Link 35, Appendix L) produces a velocity magnitude of slightly less than 2.5 ft per second. The potential for scouring of unconsolidated sediments in Outer Bolsa Bay could be prevented by channel stabilization measures provided as part of project construction.

Table 13

POSTBOL, Existing Condition
versus
NOENT2, Non-Navigable Entrance Channel Closed
and No By-Pass Connector Channel to Marina

Wetlands Not Connected

Maximum Average Channel Velocities Along Main Channel System

Location	Link No	Maximum Average Channel Velocity ft per sec	
		POSTBOL	NOENT2
Pacific Coast Highway bridge	2	2.78	3.10
Huntington Harbour	5	1.42	1.69
Huntington Harbour	7	1.48	1.78
Huntington Harbour	10	0.71	0.89
Huntington Harbour	17	0.66	0.83
Huntington Harbour	24	0.57	0.79
Huntington Harbour	25	0.30	0.47
Huntington Harbour	26	0.34	0.58
Warner Avenue bridge	34	1.65	0.67
Outer Bolsa Bay	35	1.35	2.46
Outer Bolsa Bay	36	0.71	1.18
Outer Bolsa Bay	37	0.88	1.30
Outer Bolsa Bay	38	1.12	1.79
EGG-WFCC	94	----	0.29
Channel to muted tidal wetlands	97	----	0.94

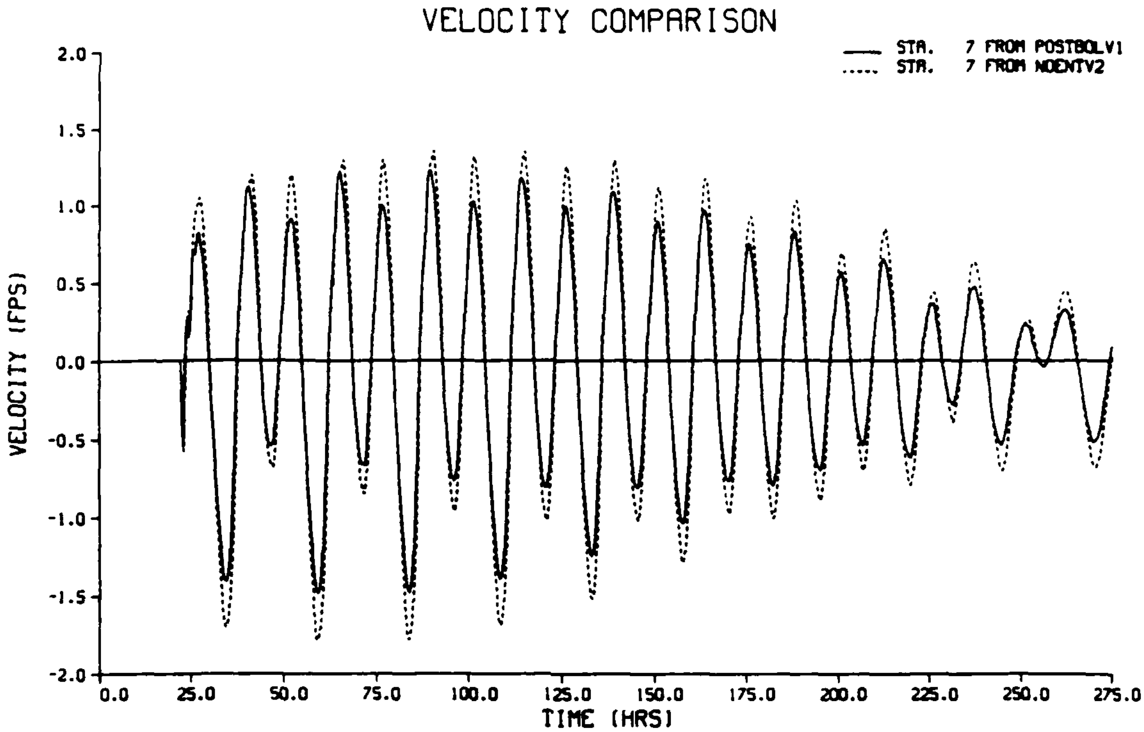


Figure 140. Average channel velocities in Huntington Harbour,
POSTBOL - existing condition
NOENTV2 - entrance channel closed and no by-pass connector to marina

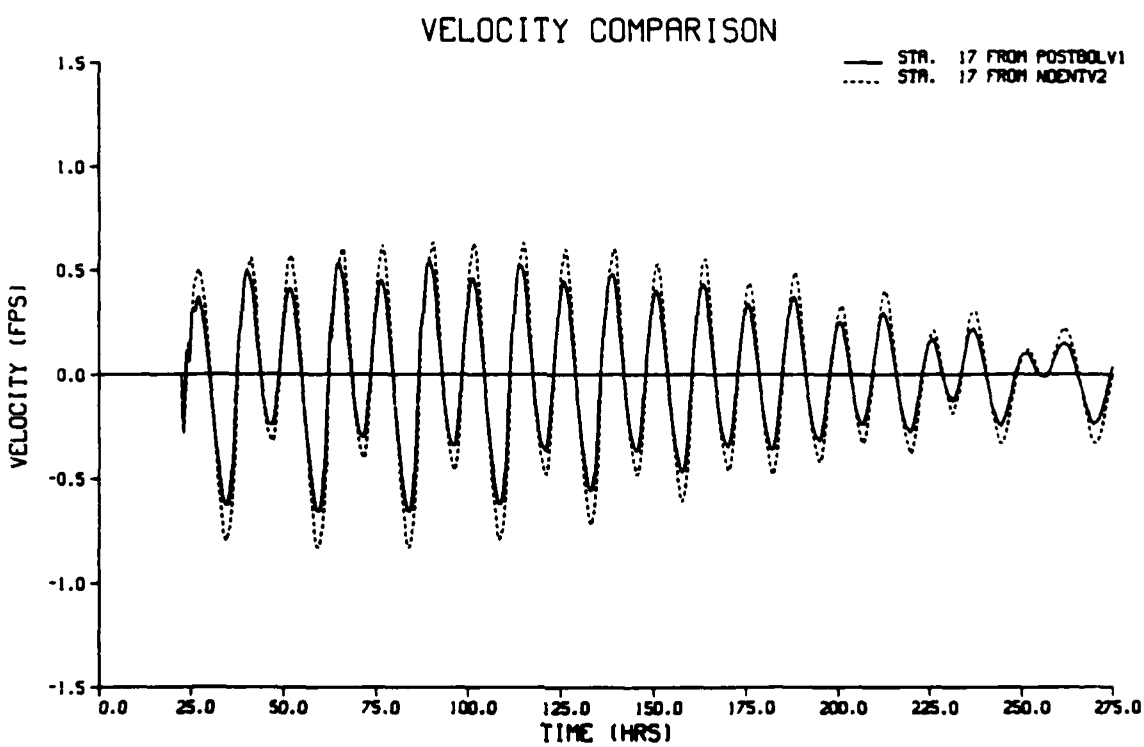


Figure 141. Average channel velocities in Huntington Harbour,
POSTBOL - existing condition
NOENTV2 - entrance channel closed and no by-pass connector to marina

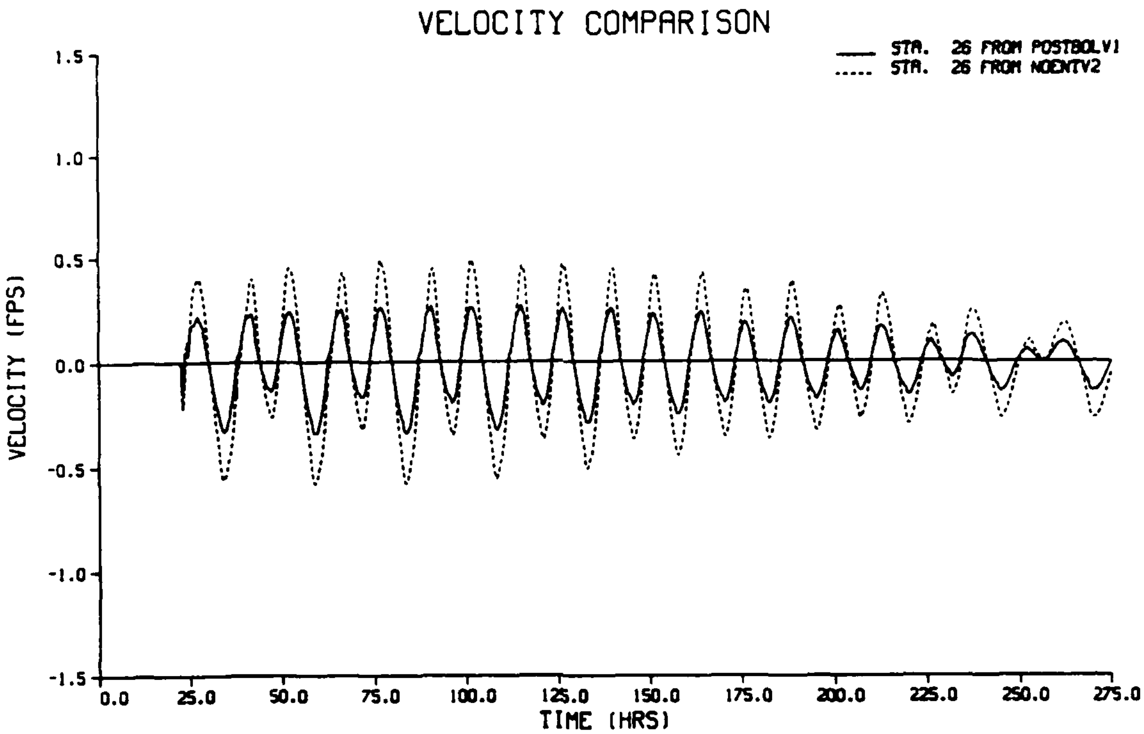


Figure 142. Average channel velocities in Huntington Harbour,
POSTBOL - existing condition
NOENTV2 - entrance channel closed and no by-pass connector to marina

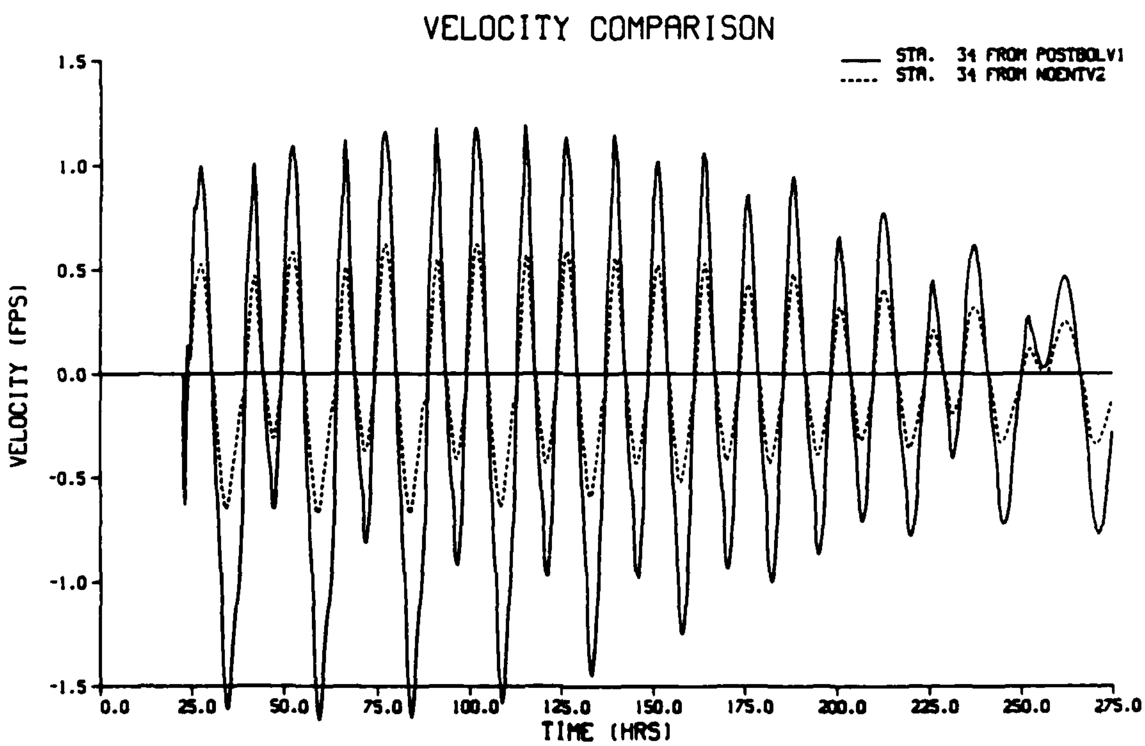


Figure 143. Average channel velocities at Warner Avenue bridge,
POSTBOL - existing condition
NOENTV2 - entrance channel closed and no by-pass connector to marina

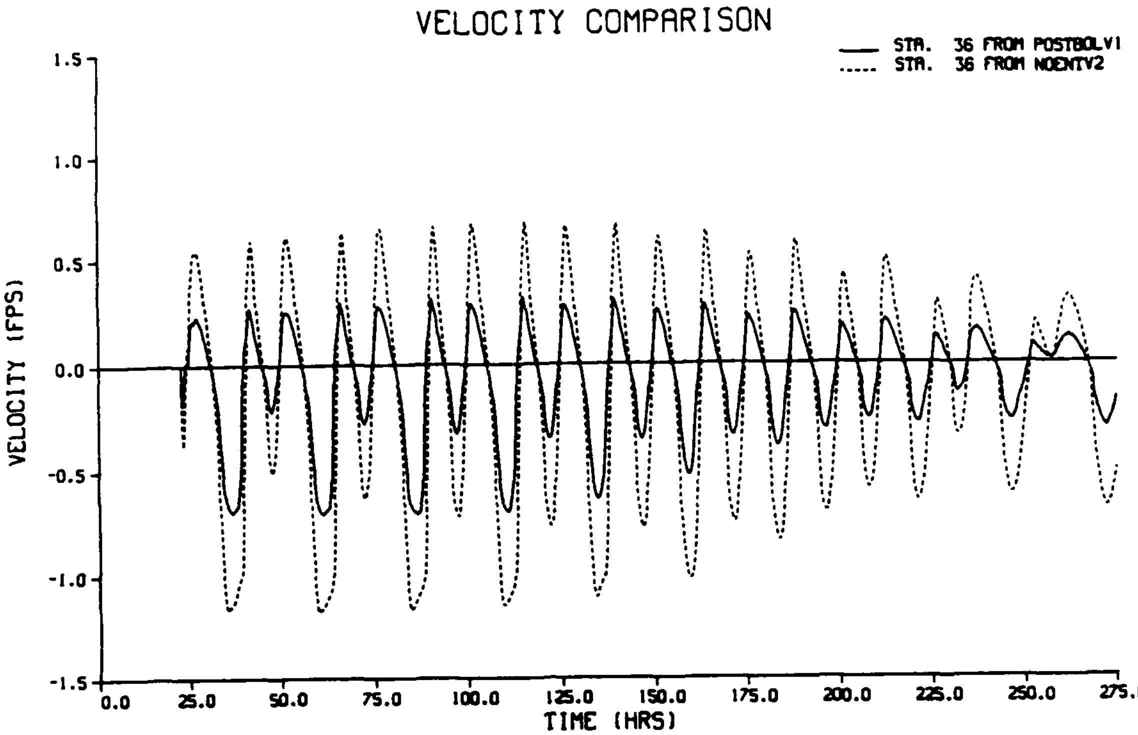


Figure 144. Average channel velocities in Outer Bolsa Bay,
POSTBOL - existing condition
NOENTV2 - entrance channel closed and no by-pass connector to marina

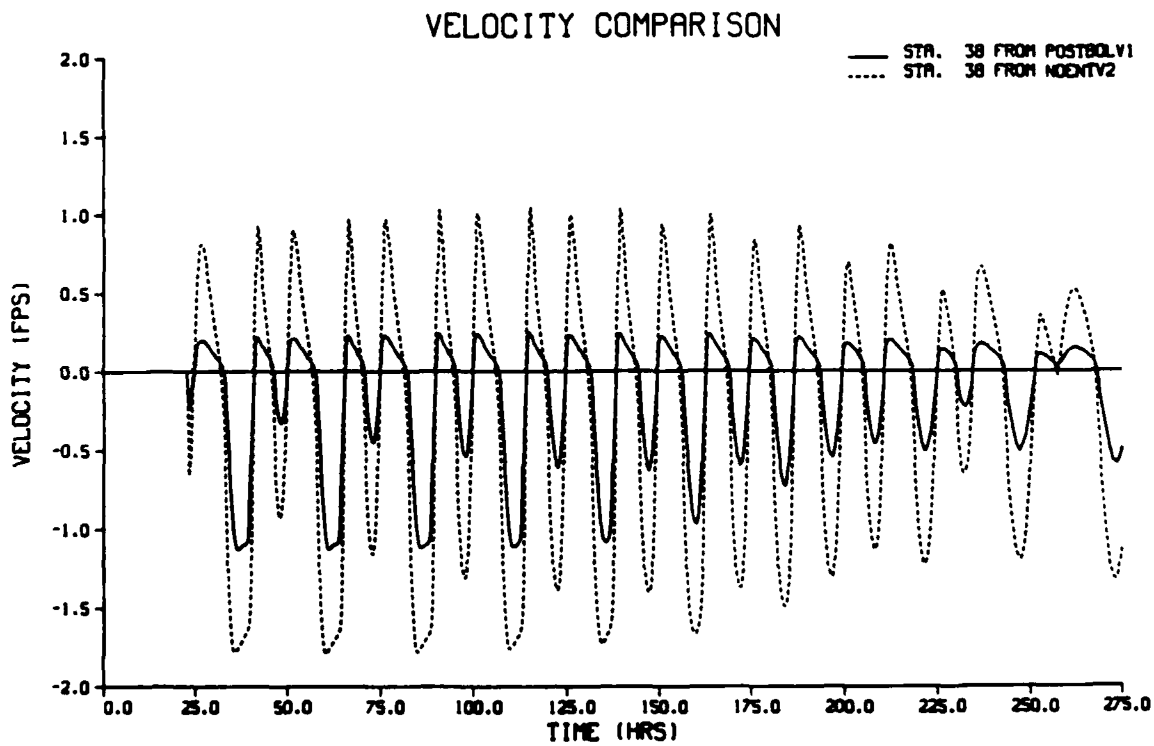


Figure 145. Average channel velocities in Outer Bolsa Bay,
POSTBOL - existing condition
NOENTV2 - entrance channel closed and no by-pass connector to marina

Effect of wetland connection

169. The effects of the existence of a wetland connection at Link 163 will not propagate through the culvert system and into Outer Bolsa Bay. All effects will be retained within both the existing wetland (Inner Bolsa Bay, and the DFG muted tidal cell) and the proposed muted tidal wetland enhancement area. The manner in which Inner Bolsa Bay responds to a connection at this location is presented in Figure 146 (Node 42), and the response of the DFG muted tidal cell (Node 54) is shown in Figure 147. Here it is seen that the channel causes a reduction in high tide elevation of around 30 percent in Inner Bolsa Bay, and around 20 percent in the DFG muted tidal cell, when compared to high tide simulations without a connector channel in place. Conversely, the connector channel causes a slight increase in tidal elevation in the proposed muted tidal wetland as displayed in Figure 148 (Node 87).

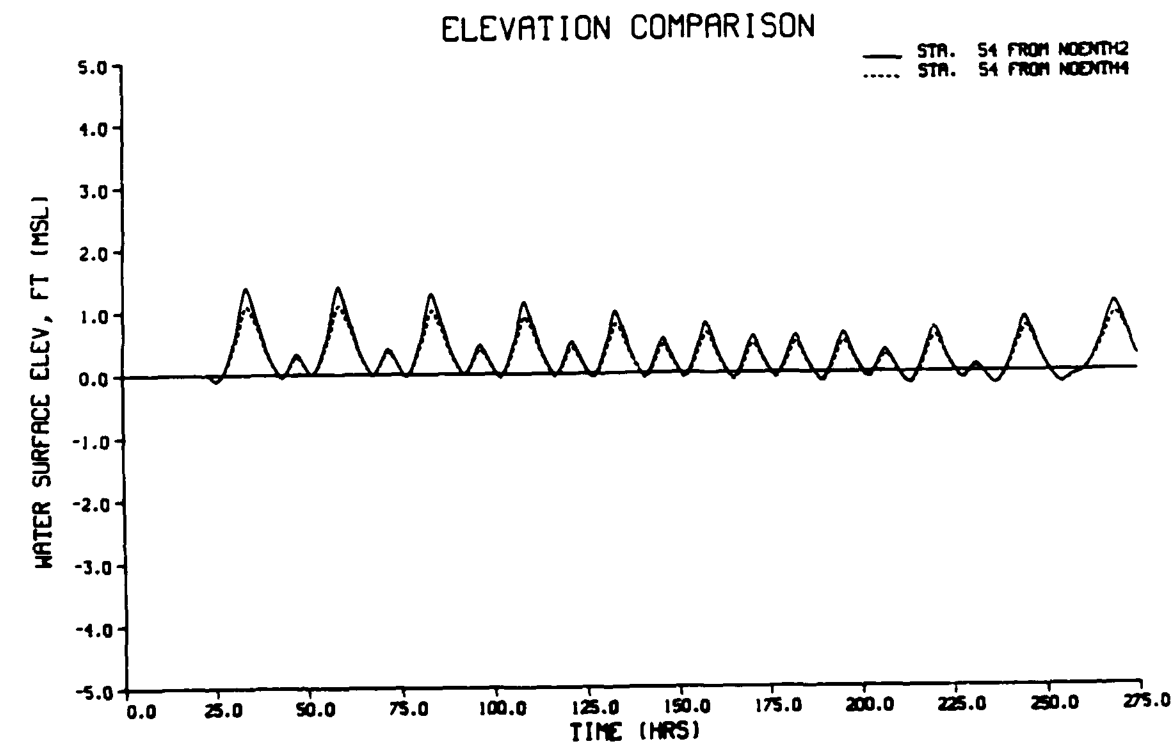


Figure 146. Effect of wetlands connection on tidal elevations, DFG muted tidal cell, non-navigable entrance and by-pass channel, NOENTH2 - wetlands not connected, NOENTH4 - wetlands connected

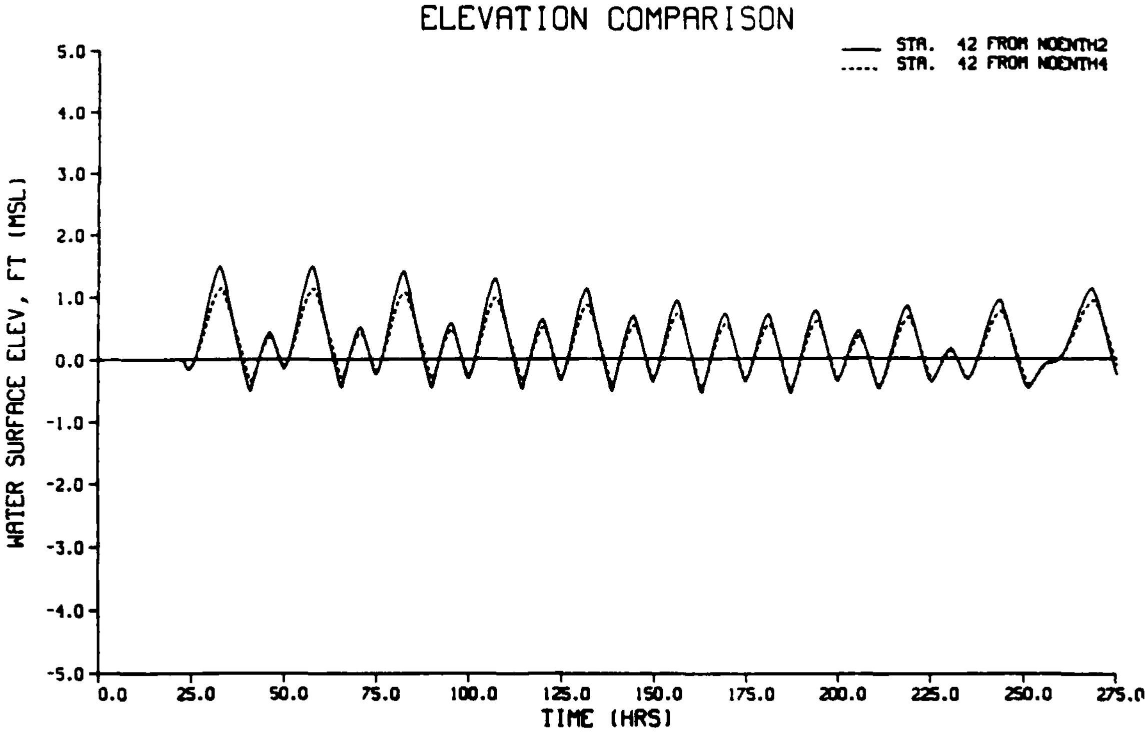


Figure 147. Effect of wetlands connection on tidal elevations, Inner Bolsa Bay, non-navigable entrance and by-pass channel, NOENTH2 - wetlands not connected, NOENTH4 - wetlands connected

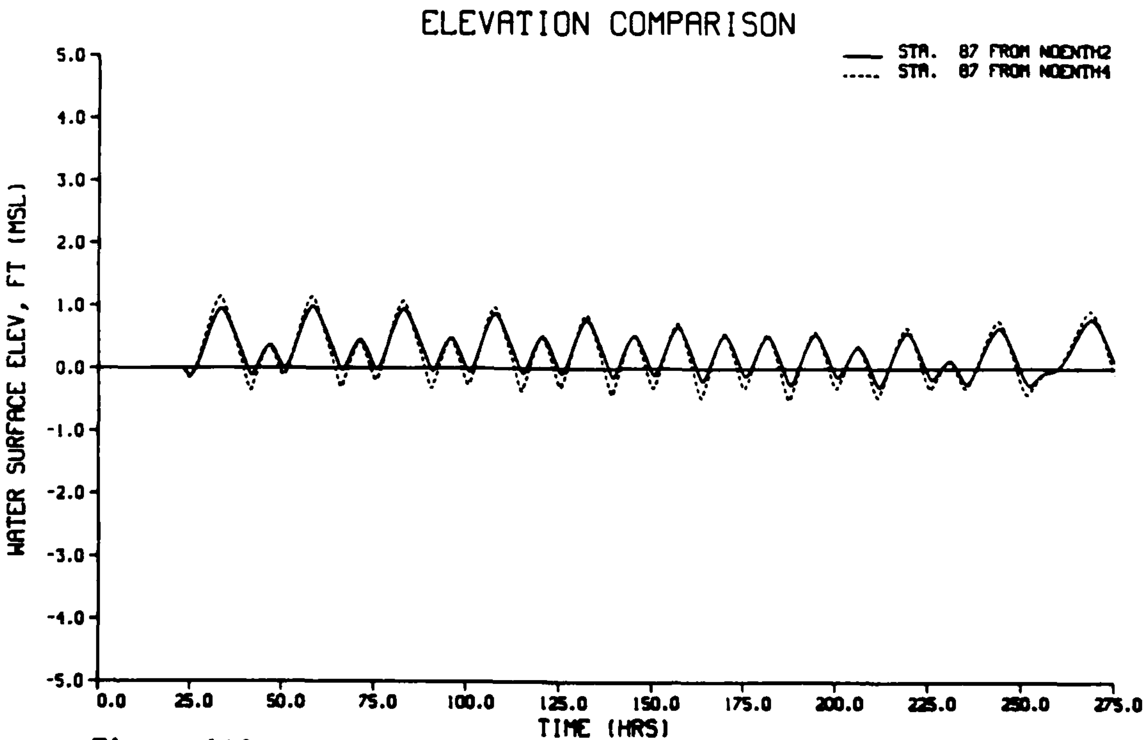


Figure 148. Effect of wetlands connection on tidal elevations, proposed muted tidal wetlands, non-navigable entrance and by-pass channel, NOENTH2 - wetlands not connected, NOENTH4 - wetlands connected

Effect of by-pass connector channel

170. The effects of a proposed by-pass connector channel also will not propagate through the culvert systems. All effects will be retained within Outer Bolsa Bay, the EGG-WFCC, and the connector channel to the proposed muted tidal wetlands. A 60 percent increase in average channel velocity in a region of Outer Bolsa Bay is shown in Figure 149 (Link 35), where velocities approach 2.5 ft per sec if the by-pass connector channel to the marina is not in place. The effect of the by-pass connector channel to the marina on tidal elevations in the EGG-WFCC for the non-navigable entrance closed concept is shown in Figure 150 (Node 80).

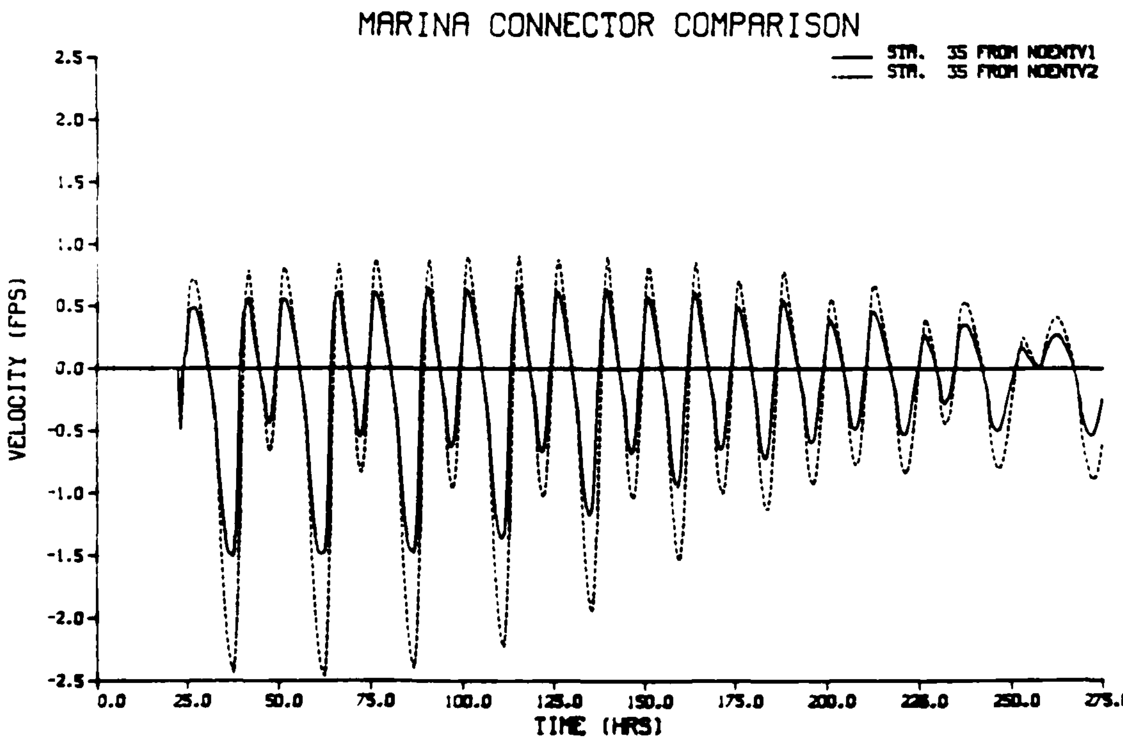


Figure 149. Effect of by-pass connector on average channel velocities, Outer Bolsa Bay, non-navigable entrance channel closed, NOENTV1 - with by-pass connector, NOENTV2 - no by-pass connector

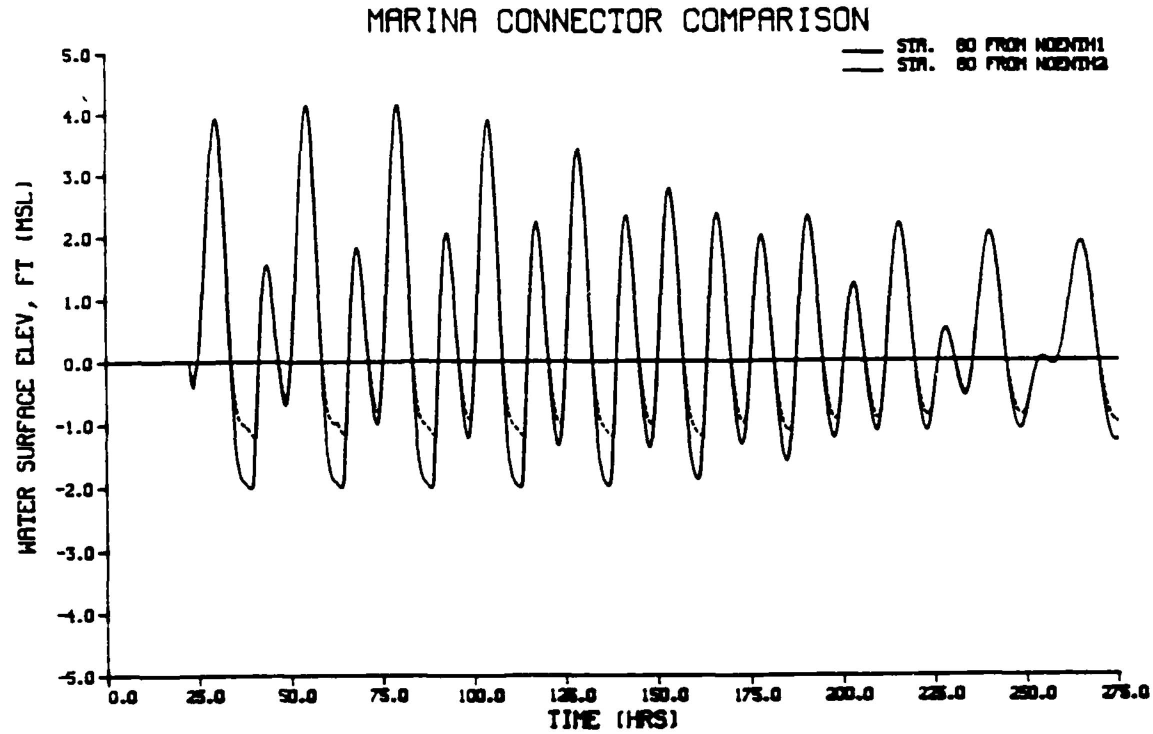


Figure 150. Effect of by-pass connector on tidal elevations, EGG-WFCC, non-navigable entrance channel closed, NOENTH1 - with by-pass connector, NOENTH2 - no by-pass connector

NOENT
Non-Navigable Entrance Channel Closed and By-Pass Connector Channel to Marina

Tidal elevations

171. The location of nodes pertinent to this concept have previously been shown on Figure 83. Tidal elevation time-histories covering the regions of interest are presented in Appendix M. Tidal ranges at representative locations are presented in Table 14. The effects of the concept of a closed non-navigable entrance channel with a by-pass connector channel to the proposed marina on water surface elevation time-histories are shown in Figures 151 through 154 for Huntington Harbour (Node 10), Outer Bolsa Bay (Node 32), Inner Bolsa Bay (Node 37), and the DFG muted tidal cell (Node 54), respectively. Time-histories also are shown in Figures 155 through 157 for Node 84 in the connector channel to the proposed muted tidal wetlands, Node 95 in the muted wetlands, and Node 126 in the by-pass channel to the marina, respectively.

Table 14

NOENT1

Non-Navigable Entrance Channel Closed
and By-Pass Connector Channel to Marina

Wetlands Not Connected

Tide Ranges at Representatives Nodes

Location	Node No	High Tide feet, msl	Low Tide feet, msl
Huntington Harbour	10	4.10	-4.10
Outer Bolsa Bay	29	4.10	-4.10
Outer Bolsa Bay	30	4.10	-2.87
Outer Bolsa Bay	31	4.09	-2.77
Outer Bolsa Bay	32	4.09	-2.48
Outer Bolsa Bay	33	4.09	-2.03
Inner Bolsa Bay	37	1.48	-0.60
Inner Bolsa Bay	45	1.49	-0.61
Inner Bolsa Bay	50	1.48	-0.60
DFG muted tidal cell	54	1.38	-0.04
Proposed marina	77	4.10	-3.98
EGG-WFCC	82	4.09	-1.97
Channel to muted tidal wetlands	84	4.09	-1.65
Proposed muted tidal wetlands	95	0.98	-0.15
Proposed muted tidal wetlands	108	0.98	-0.15
By-pass channel to marina	126	4.10	-2.42

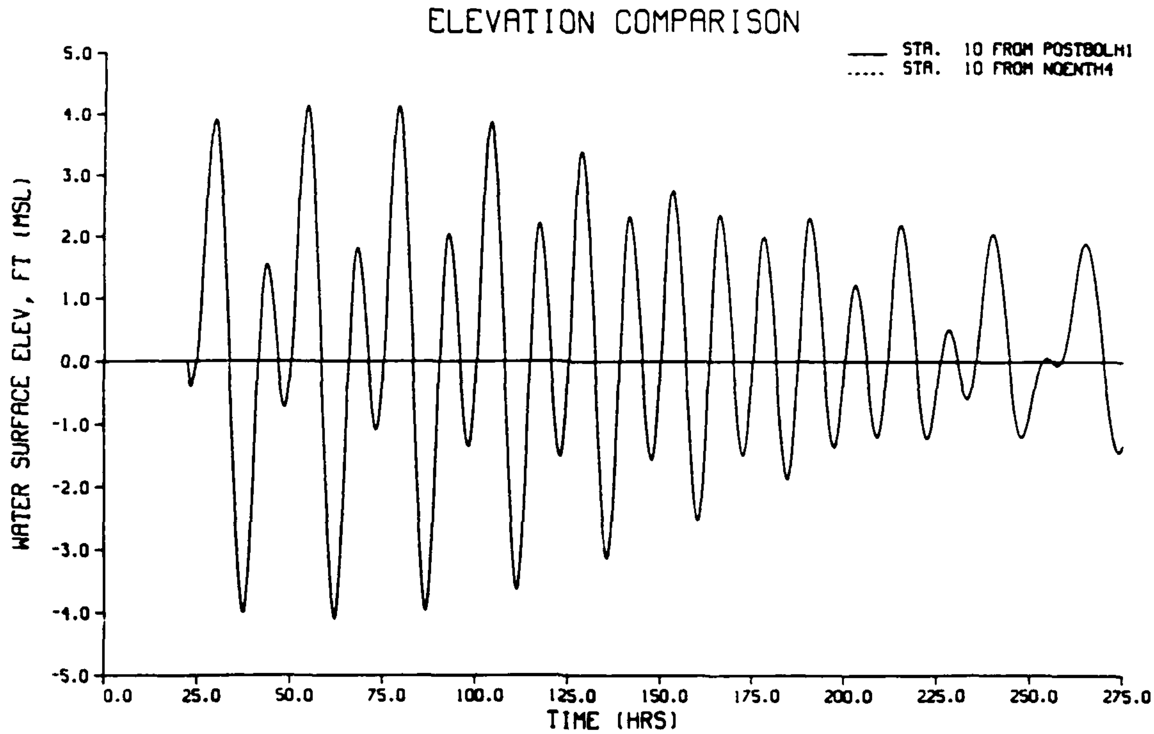


Figure 151. Tidal elevations in Huntington Harbour,
POSTBOL - existing condition
NOENTH4 - entrance channel closed and by-pass connector to marina

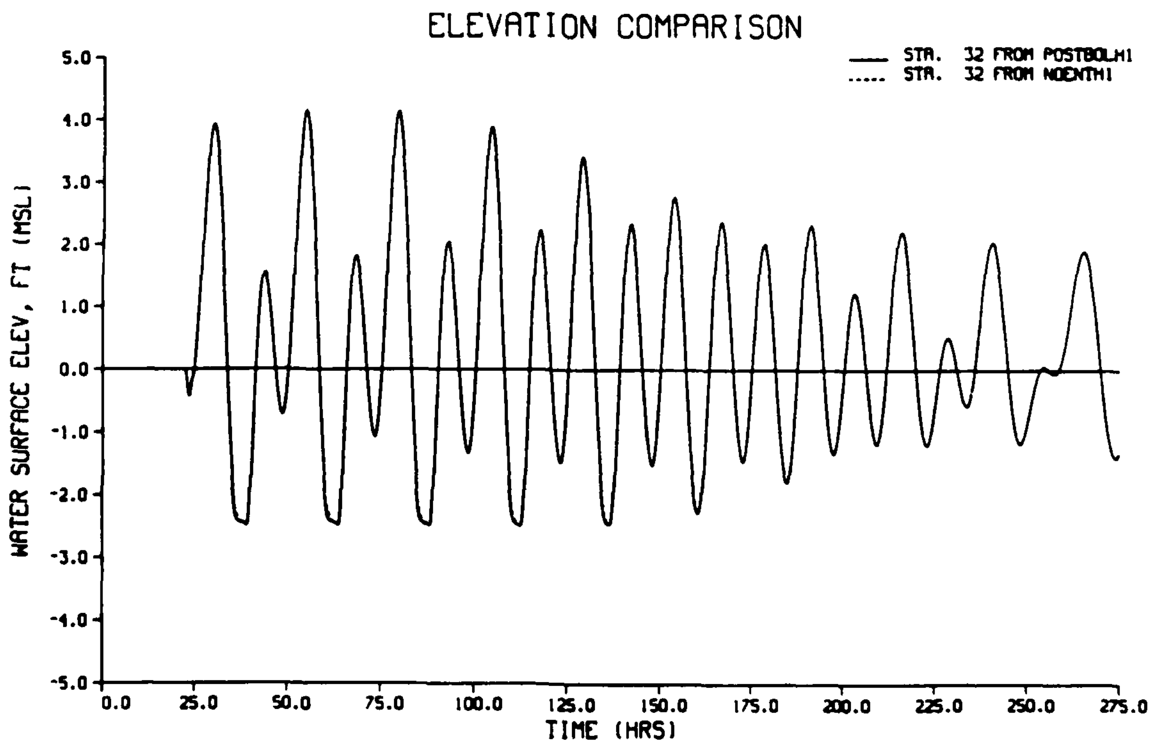


Figure 152. Tidal elevations in Outer Bolsa Bay,
POSTBOL - existing condition
NOENTH1 - entrance channel closed and by-pass connector to marina

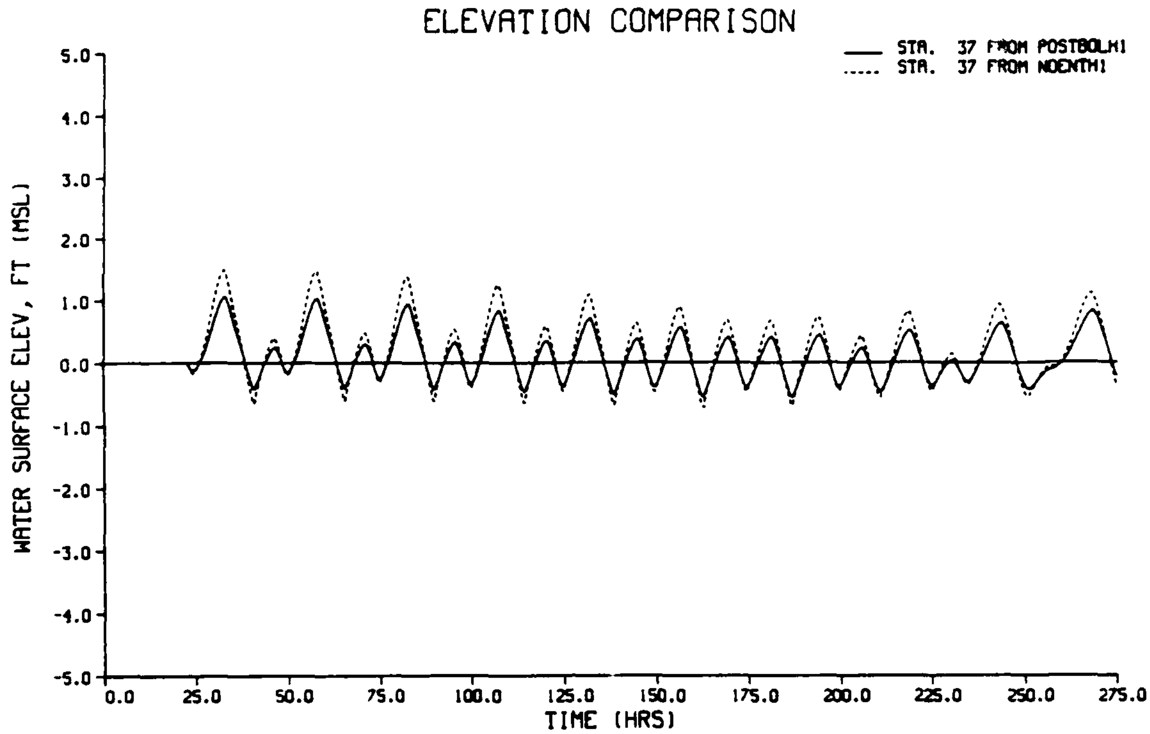


Figure 153. Tidal elevations in Inner Bolsa Bay,
POSTBOL - existing condition
NOENTH1 - entrance channel closed and by-pass connector to marina

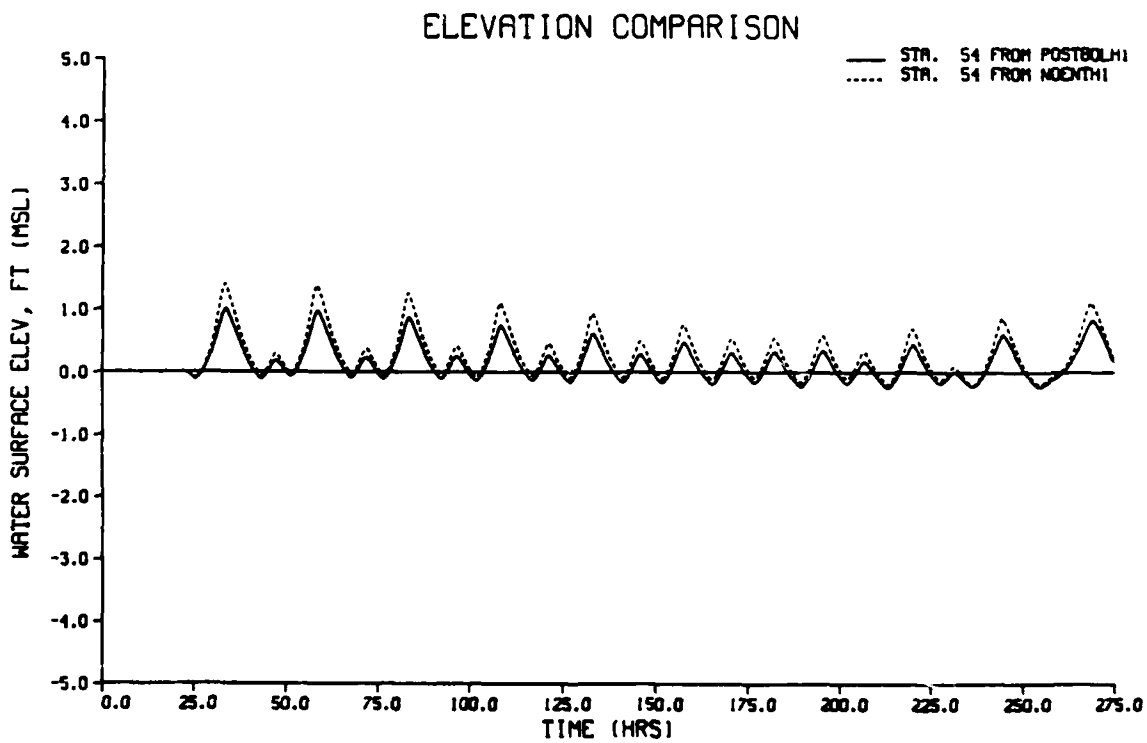


Figure 154. Tidal elevations in DFG muted tidal cell,
POSTBOL - existing condition
NOENTH1 - entrance channel closed and by-pass connector to marina

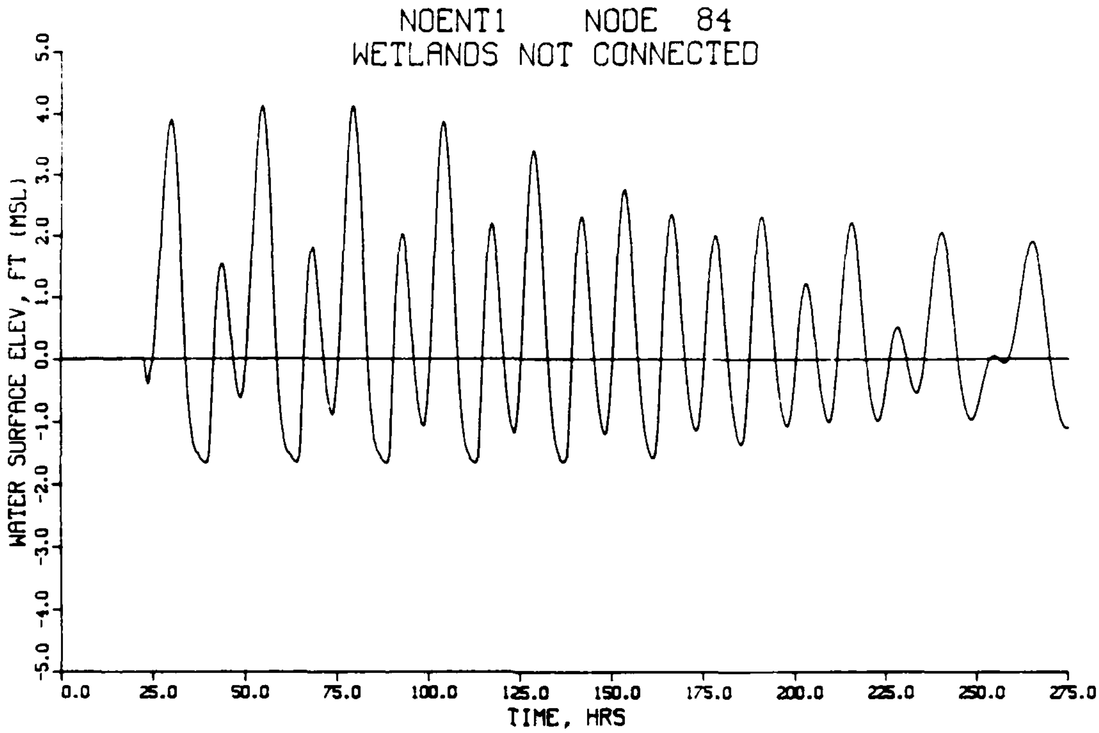


Figure 155. Tidal elevations in channel to proposed muted tidal wetlands under entrance channel closed and by-pass connector channel to proposed marina conditions, NOENTH1

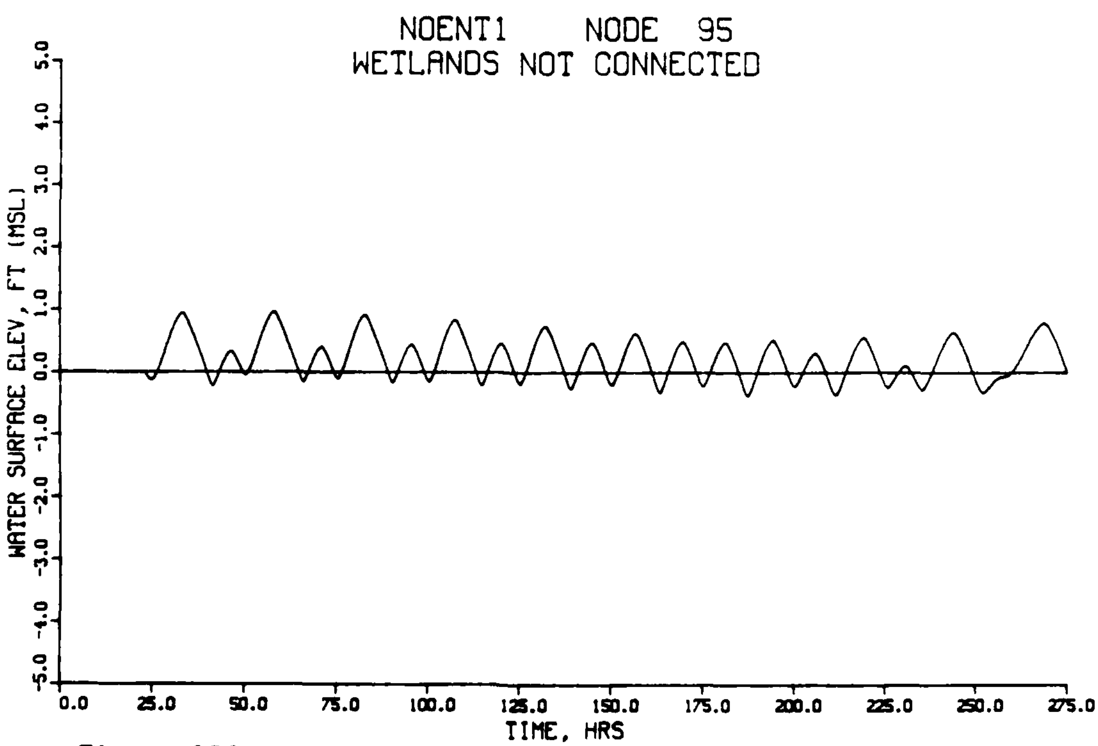


Figure 156. Tidal elevations in proposed muted tidal wetlands under entrance channel closed and by-pass connector channel to proposed marina conditions, NOENTH1

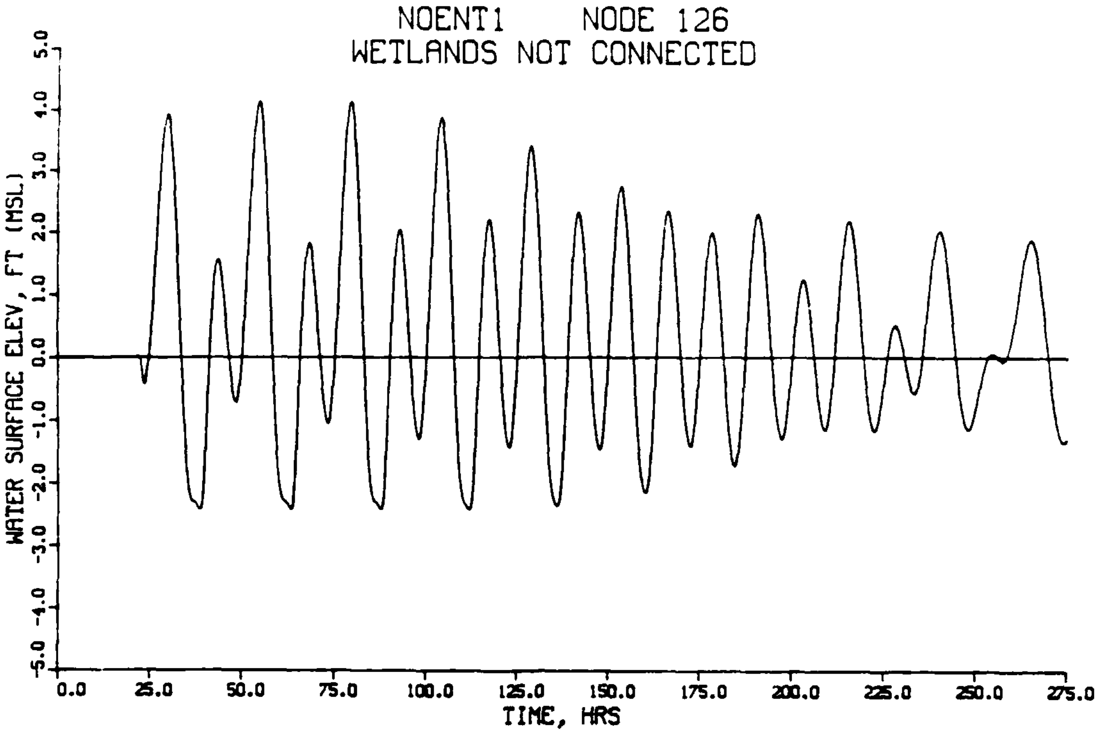


Figure 157. Tidal elevations in by-pass channel to proposed marina under entrance channel closed conditions, NOENTH1

<u>Velocities</u>

172. Links pertinent to this phase of the investigation have been previously shown on Figure 82. Average channel velocities at the links of interest are presented in Appendix M. Maximum average channel velocities resulting from the closed non-navigable entrance channel concept with a by-pass connector channel to the marina for all links along the main Huntington Harbour channel and Outer Bolsa Bay are compared with existing condition velocities in Table 15. The effects of this concept on typically representative average channel velocity time-histories are shown in Figures 158 through 163 in Huntington Harbour (Links 7, 17, and 26), at the location of the previous Warner Avenue bridge (Link 34), and in Outer Bolsa Bay (Links 36 and 38).

173. Two links comprising the by-pass connector channel to the marina are shown in Figures 164 and 165, (Links 89 and 162, respectively). Under ebb tide conditions, the proposed marina empties faster than water can flow into it through the by-pass channel, and a hydraulic head is created which causes non-uniform depth of flow in the channel. This results in a different average

channel velocity at every location along the channel, as reflected in Figures 164 and 165.

Table 15

POSTBOL, Existing Condition
versus
NOENT1, Non-Navigable Entrance Channel Closed
and By-Pass Connector Channel to Marina

Wetlands Not Connected

Maximum Average Channel Velocities Along Main Channel System

Location	Link No	Maximum Average Channel Velocity ft per sec POSTBOL	NOENT1
Pacific Coast Highway bridge	2	2.78	3.13
Huntington Harbour	5	1.42	1.74
Huntington Harbour	7	1.48	1.84
Huntington Harbour	10	0.71	0.92
Huntington Harbour	17	0.66	0.87
Huntington Harbour	24	0.57	0.83
Huntington Harbour	25	0.30	0.50
Huntington Harbour	26	0.34	0.63
Warner Avenue bridge	34	1.65	0.74
Outer Bolsa Bay	35	1.35	1.49
Outer Bolsa Bay	36	0.71	0.84
Outer Bolsa Bay	37	0.88	0.90
Outer Bolsa Bay	38	1.12	1.23
EGG-WFCC	94	----	0.41
Channel to muted tidal wetlands	97	----	1.22
By-pass channel to marina	89	----	2.18
By-pass channel to marina	162	----	3.16

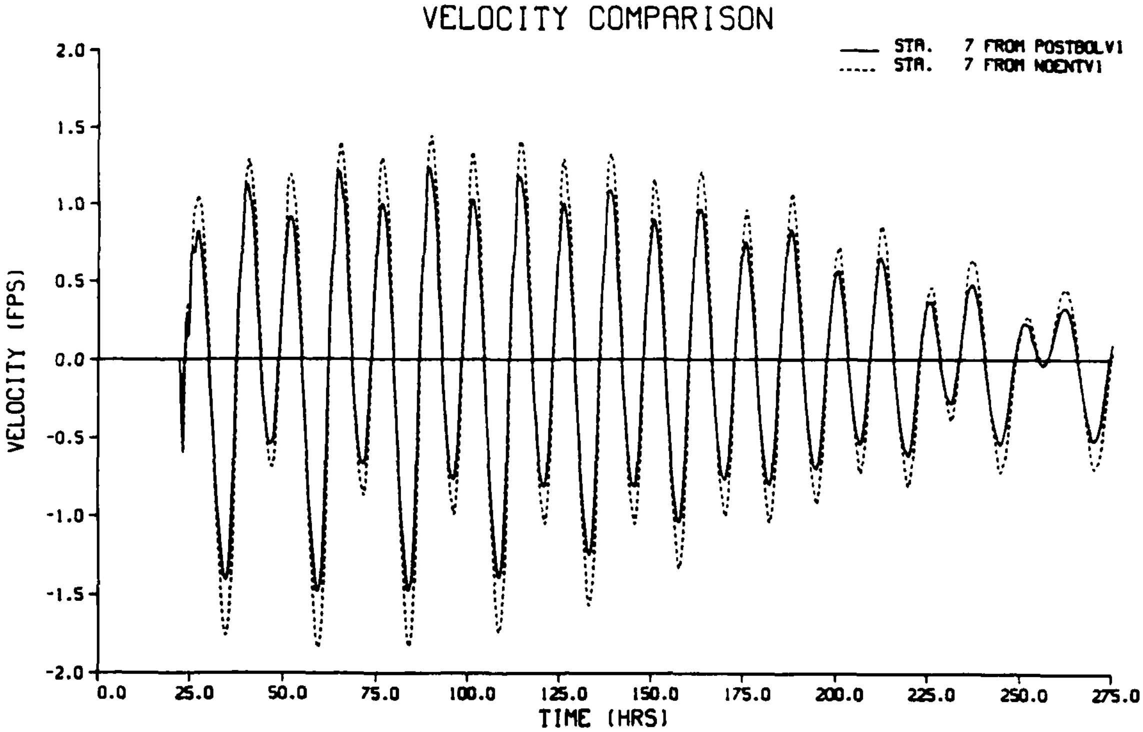


Figure 158. Average channel velocities in Huntington Harbour,
POSTBOL - existing condition
NOENTV1 - entrance channel closed and by-pass connector to marina

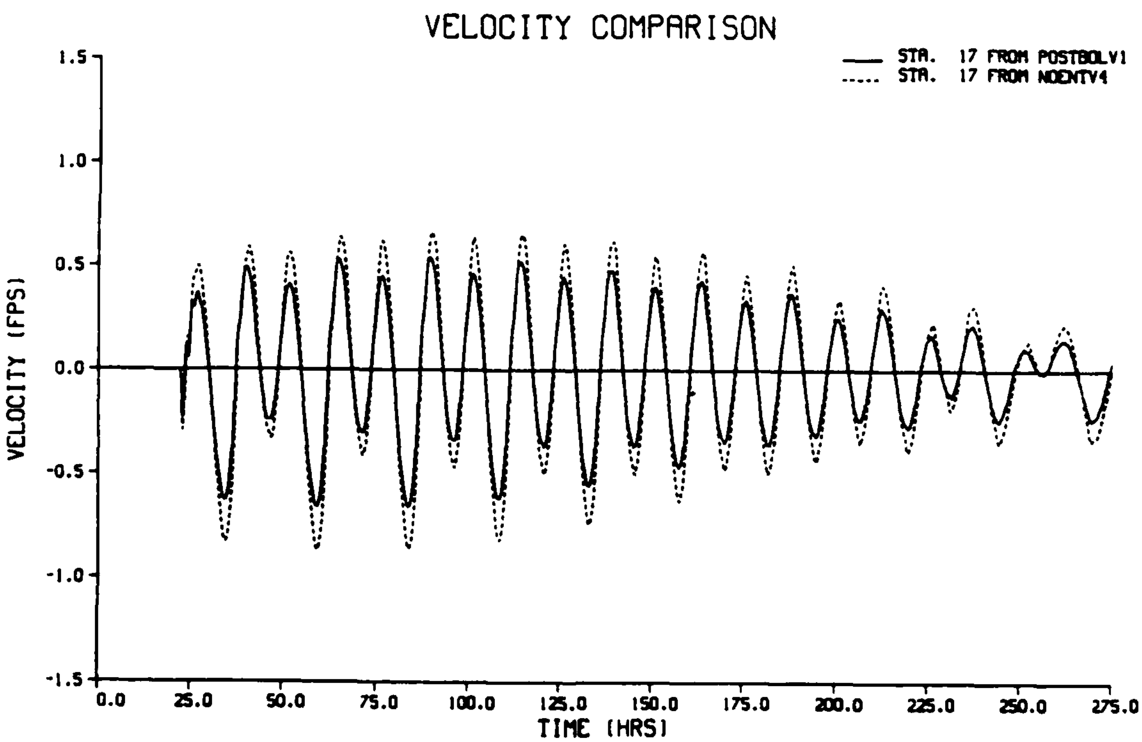


Figure 159. Average channel velocities in Huntington Harbour,
POSTBOL - existing condition
NOENTV4 - entrance channel closed and by-pass connector to marina

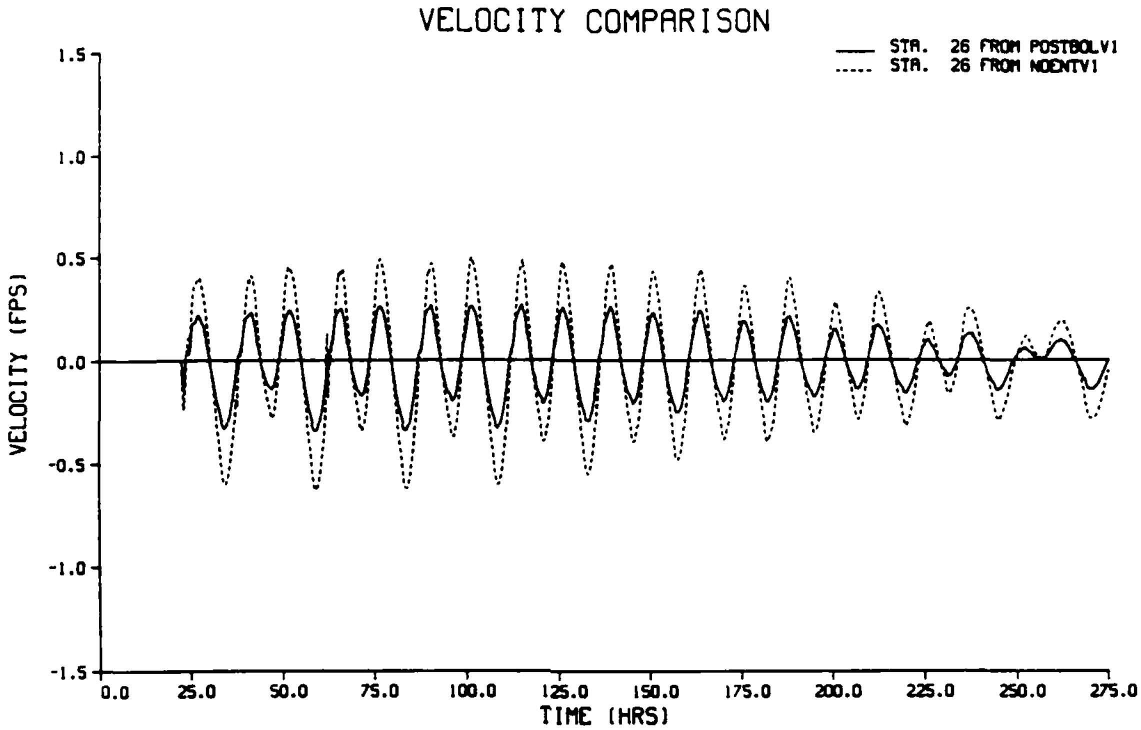


Figure 160. Average channel velocities in Huntington Harbour,
POSTBOL - existing condition
NOENTV1 - entrance channel closed and by-pass connector to marina

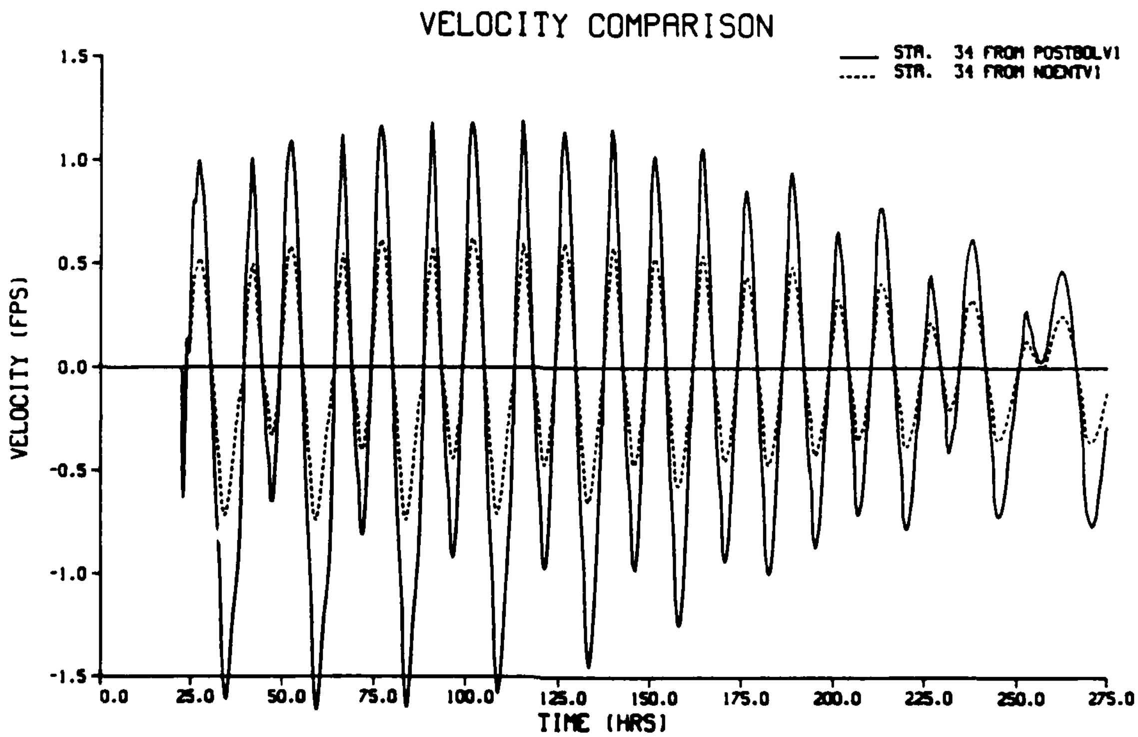


Figure 161. Average channel velocities at Warner Avenue bridge,
POSTBOL - existing condition
NOENTV1 - entrance channel closed and by-pass connector to marina

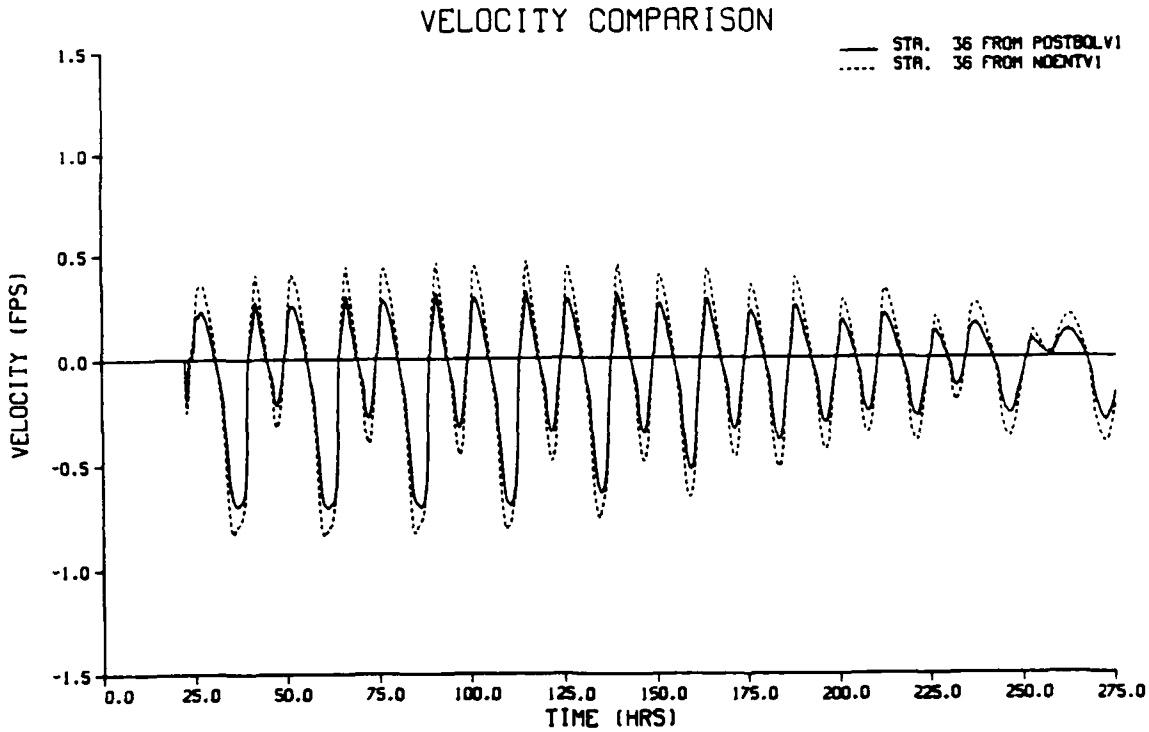


Figure 162. Average channel velocities in Outer Bolsa Bay,
POSTBOL - existing condition
NOENTV1 - entrance channel closed and by-pass connector to marina

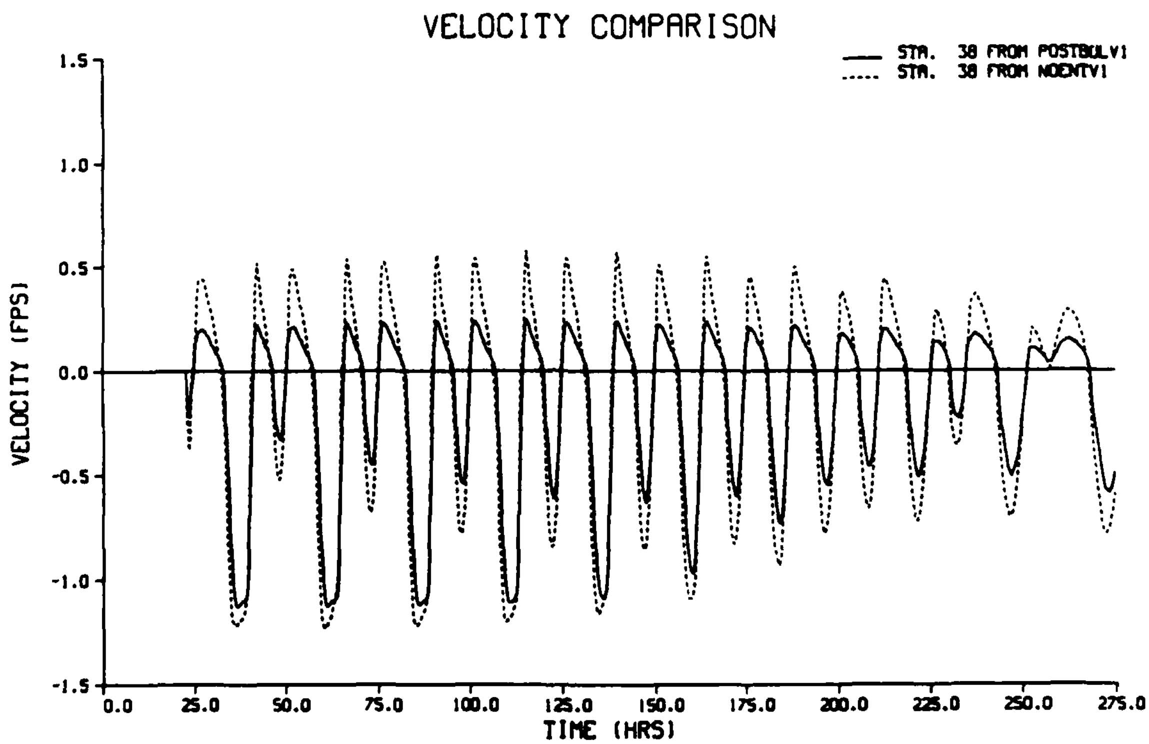


Figure 163. Average channel velocities in Outer Bolsa Bay,
POSTBOL - existing condition
NOENTV1 - entrance channel closed and by-pass connector to marina

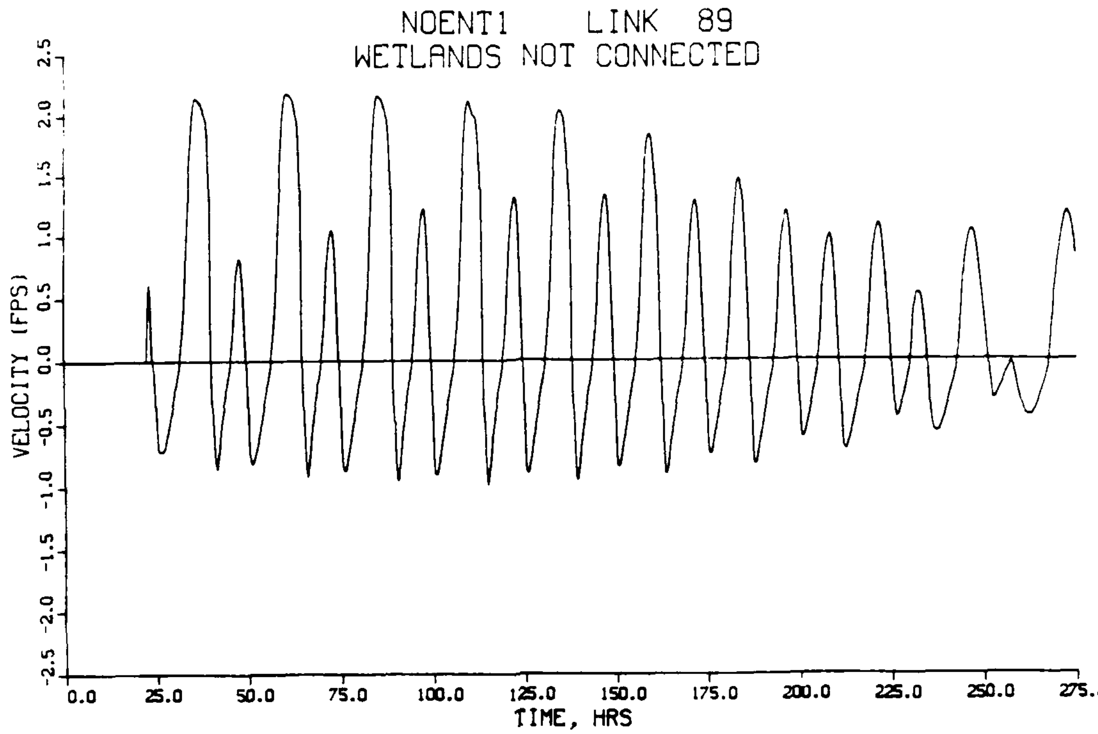


Figure 164. Average channel velocities in by-pass channel to proposed marina under entrance channel closed conditions, NOENTV1

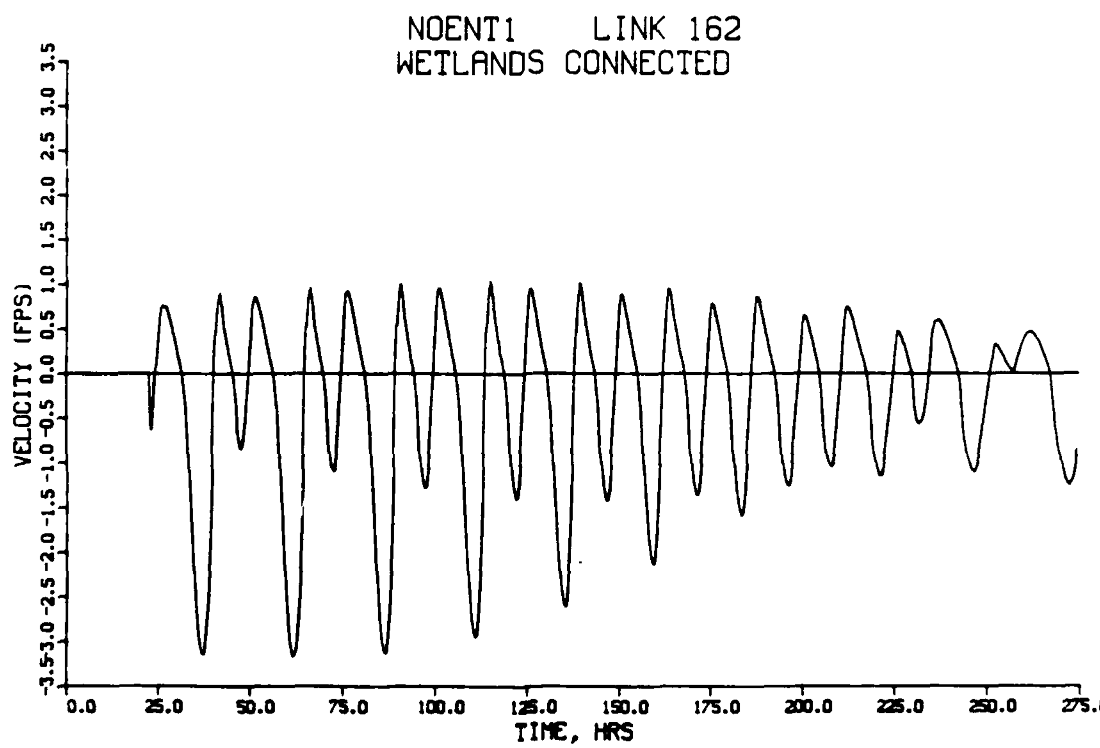


Figure 165. Average channel velocities in by-pass channel to proposed marina under entrance channel closed conditions, NOENTV1

PART IX: HYDRODYNAMIC COMPARISON OF EXISTING CONDITION WITH PROPOSED ALTERNATIVE DESIGN CONCEPTS

174. Characteristics of the 12 variations of proposed alternative new new entrance channels, marinas, and wetland enhancements are compared and contrasted. The features regarding whether the entrance channel is navigable, whether the connector channel to Huntington Harbour is navigable, whether the wetlands are connected internally, and whether there is a by-pass connector channel to the proposed new marina with the non-navigable entrance channel concept, are indicated in Table 16. Also shown is the code utilized for displaying hydrodynamic simulation results of tidal elevations and average channel velocities for the 12 variations of alternatives.

POSTBOL versus NENC versus NNECC Comparison of Existing Condition with Navigable and Non-Navigable Entrance Channel

175. The hydrodynamic characteristics (tidal elevations and average channel velocities) for the existing conditions have been compared with the simulations for the conceptual designs of a navigable entrance channel with a navigable connector channel to Huntington Harbour (Preferred Alternative), and

Table 16

Bolsa Bay, California, Hydrodynamic Simulations

Code	Entrance Channel	Connector Channel to Huntington Harbour	Wetlands Connected	Connector Channel to Marina
POSTBOL	None	Non-Navigable	---	---
NENC1	Navigable	Navigable	Yes	---
NENC2	Navigable	Navigable	No	---
NENNC1	Navigable	Non-Navigable	Yes	---
NENNC2	Navigable	Non-Navigable	No	---
NNECC1	Non-Navigable	Non-Navigable	No	Yes
NNECC2	Non-Navigable	Non-Navigable	No	No
NNECC3	Non-Navigable	Non-Navigable	Yes	Yes
NNECC4	Non-Navigable	Non-Navigable	Yes	No
NOENT1	Closed	Non-Navigable	No	Yes
NOENT2	Closed	Non-Navigable	No	No
NOENT3	Closed	Non-Navigable	Yes	No
NOENT4	Closed	Non-Navigable	Yes	Yes

a non-navigable entrance channel (Secondary Alternative). The non-navigable entrance channel simulations which are displayed in the following figures were computed for the condition where a non-navigable channel connects the proposed new marina at Warner Avenue with the EGG-WFCC channel.

Tidal elevations

176. Huntington Harbour has the ability to fill and empty entirely through the Anaheim Bay entrance, regardless of whether any engineering works of improvement or wetland enhancements are performed in Bolsa Bay. Hence, for all conditions, the tidal amplitudes in Huntington Harbour are essentially unaltered by simulated modifications elsewhere in the bay system (Figure 166).

177. High tide elevations in Outer Bolsa Bay rise to the same level regardless of which type of entrance is installed. Outer Bolsa Bay has the ability to fill from Huntington Harbour, or it will fill from either of the proposed new entrances to Bolsa Bay. The low water elevations in Outer Bolsa Bay, especially at large tide range, depend on the type of connection to the ocean. For existing conditions, where all flow to the existing wetlands passes through Outer Bolsa Bay, the hydrography and boundary friction

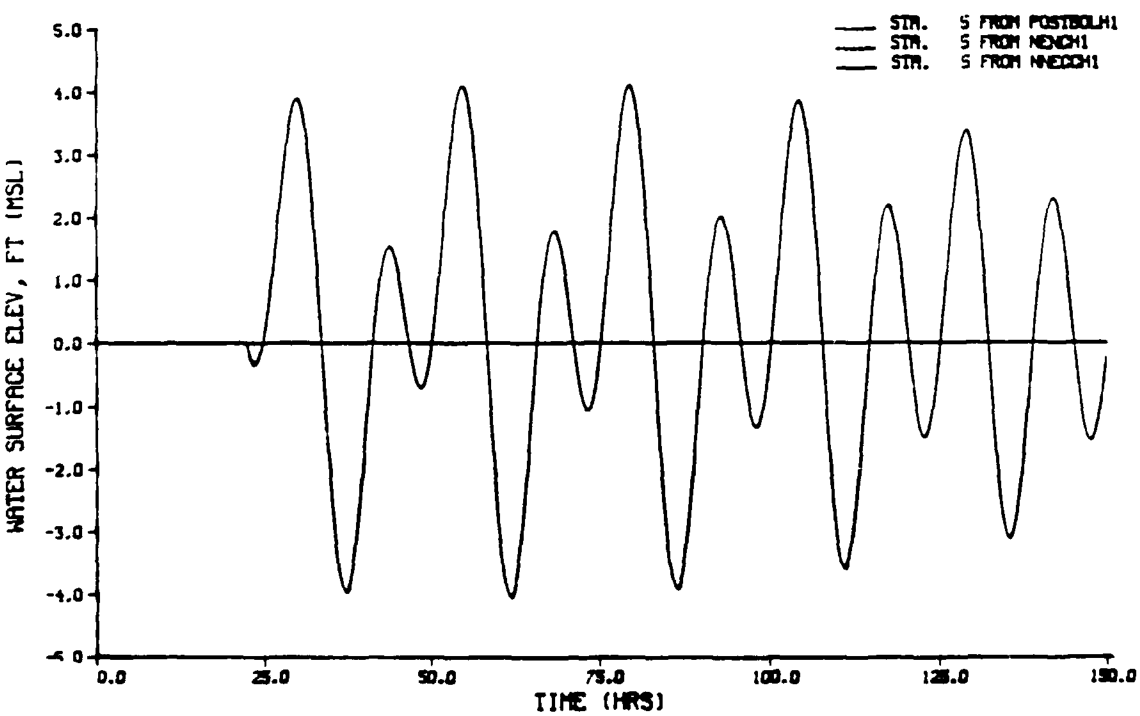


Figure 166. Huntington Harbour, POSTBOL - existing condition, NENCH1 - navigable entrance, navigable channel to Huntington Harbour, NNECCH1 - non-navigable entrance and channel to Huntington Harbour

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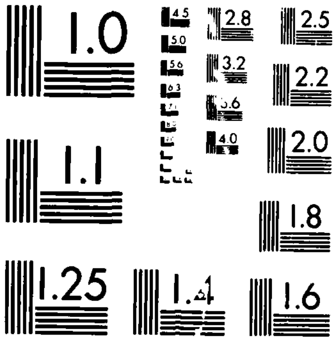

1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6
6.3

characteristics prevent low tide elevations from falling as far as low tide elevations in Huntington Harbour. A navigable entrance with a navigable connector channel through Outer Bolsa Bay to Huntington Harbour will allow low tide to reflect the water surface elevation in the ocean. The non-navigable entrance is designed to operate with a non-navigable connector channel to Huntington Harbour. Hence, Outer Bolsa Bay will remain in its present condition. The new non-navigable entrance, although relatively small (160 ft wide at the bottom, with a bottom elevation of -5 ft msl), will convey a large portion of the tidal prism of the enhanced wetlands. The nearness of the entrance to Outer Bolsa Bay will permit the low water elevations in Outer Bolsa Bay to fall lower than for the existing condition, but not to the extent that a navigable connector channel would allow (Figures 167).

178. The tide gates and culvert systems to the existing, and proposed full and muted tidal wetlands, are distinctly different, depending on whether a navigable or non-navigable entrance channel concept is considered. Therefore, the existing muted tidal wetlands of Inner Bolsa Bay respond differently based on these two situations, and on whether Inner Bolsa Bay is connected to

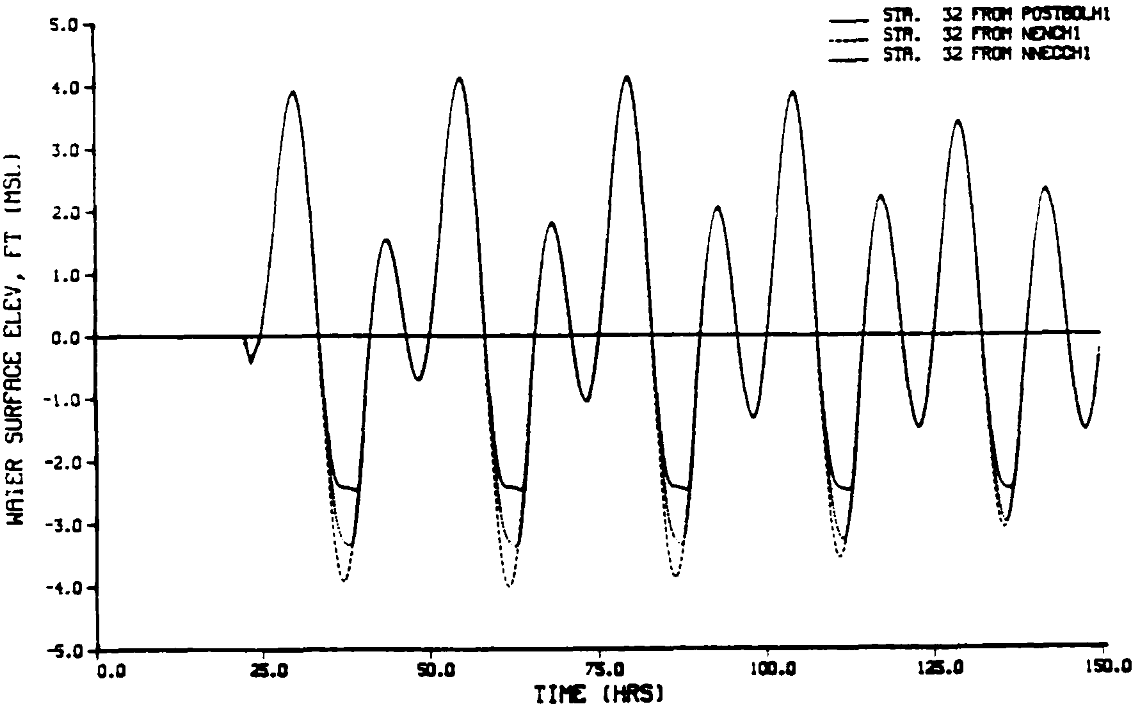


Figure 167. Outer Bolsa Bay, POSTBOL - existing condition, NENCH1 - navigable entrance, navigable channel to Huntington Harbour, NNECCH1 - non-navigable entrance and channel to Huntington Harbour

the proposed new muted tidal wetlands. When the wetlands are connected, high water elevation in Inner Bolsa Bay rises slightly above existing conditions for the navigable entrance channel concept, while remaining essentially at the existing tide range for the non-navigable entrance channel concept (Figure 168). This response is essentially duplicated in the DFG muted tidal cell (Figure 169). If the proposed muted tidal wetlands are not connected to Inner Bolsa Bay, each wetland area operates independently. In this case, for the tide gate and culvert systems under consideration, both the navigable and non-navigable entrance channel concepts will cause about a 30 percent increase in high tide elevation. However, because the tide range in Inner Bolsa Bay and the DFG muted tidal cell is quite limited (on the order of 1.5 ft), a 30 percent increase is not a large rise in absolute magnitude (Figures 170 and 171).

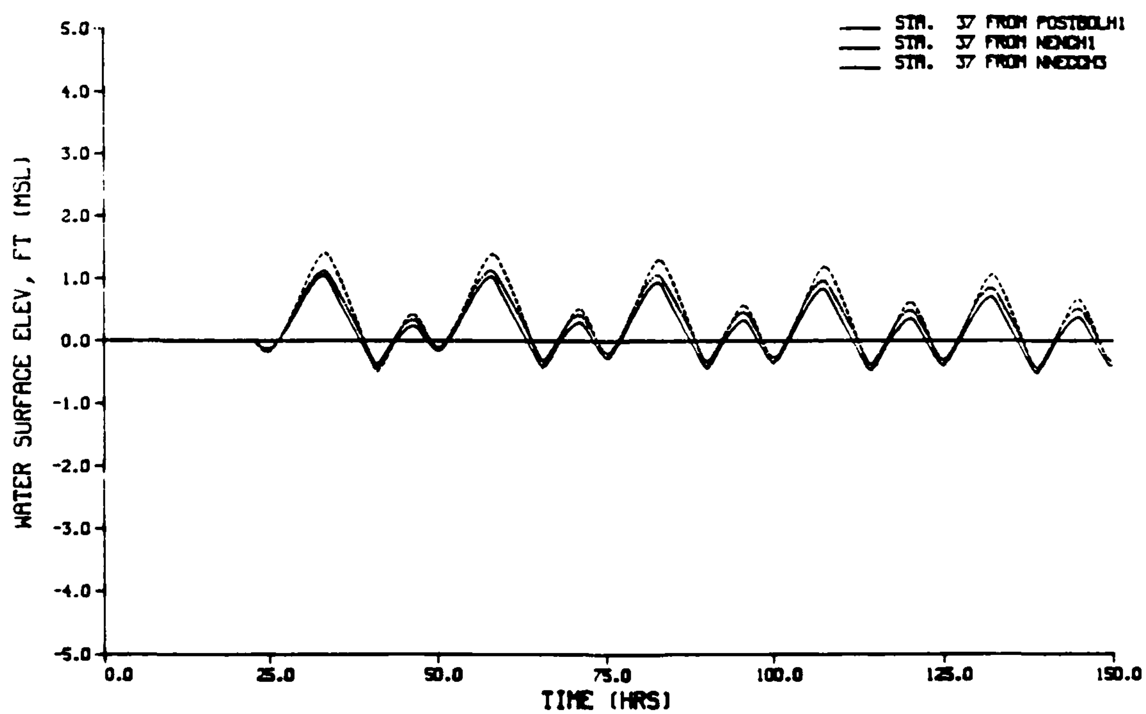


Figure 168. Inner Bolsa Bay, wetlands connected, POSTBOL - existing condition, NENCH1 - navigable entrance, navigable channel to Huntington Harbour, NNECCH3 - non-navigable entrance and channel to Huntington Harbour

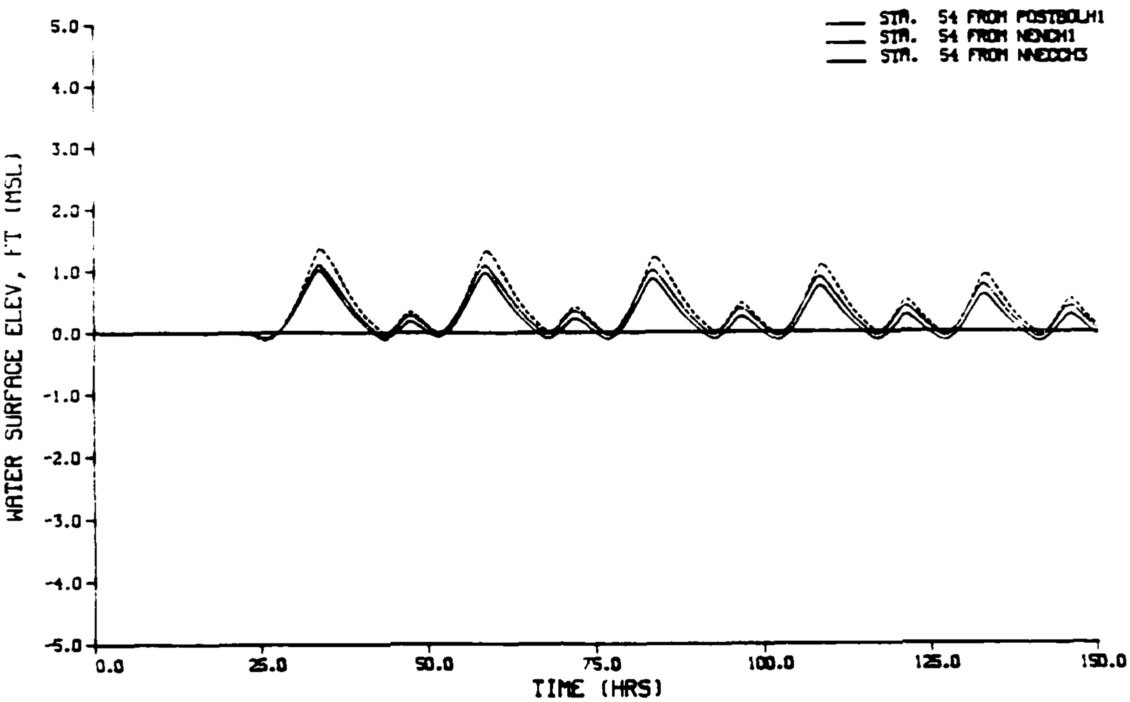


Figure 169. DFG muted cell, wetlands connected, POSTBOL - existing condition, NENCH1 - navigable entrance, navigable channel to Huntington Harbour, NNECCH3 - non-navigable entrance and channel to Huntington Harbour

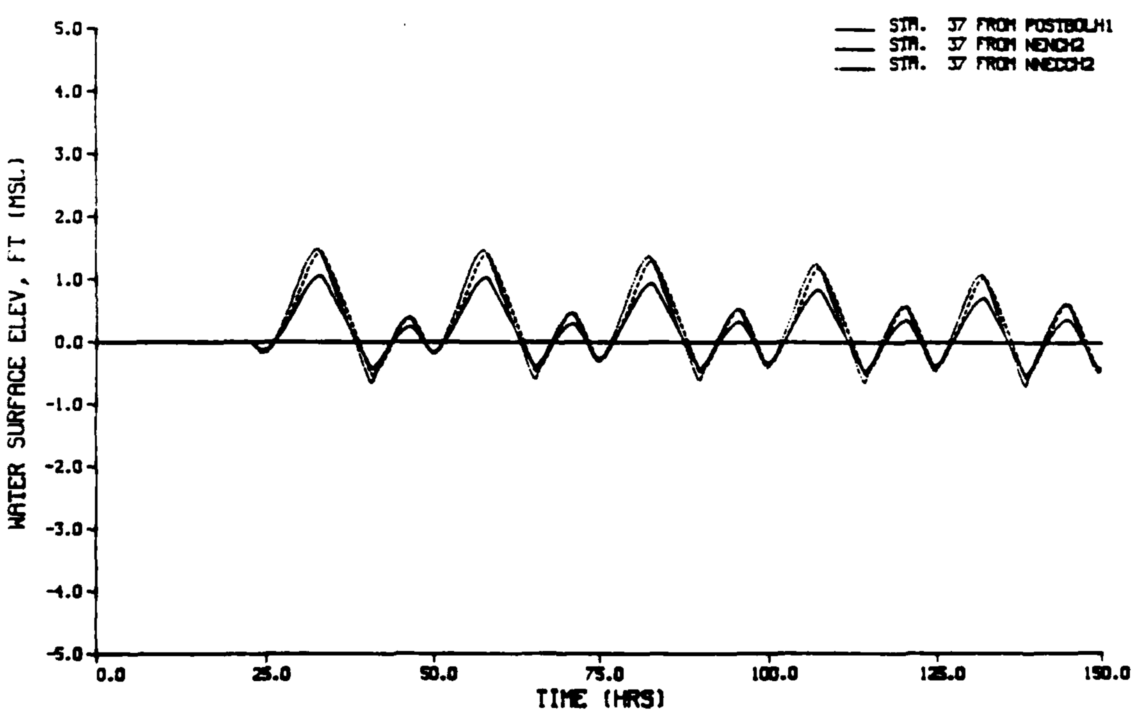


Figure 170. Inner Bay, wetlands not connected, POSTBOL - existing condition, NENCH2 - navigable entrance, navigable channel to Huntington Harbour, NNECCH2 - non-navigable entrance and channel to Huntington Harbour

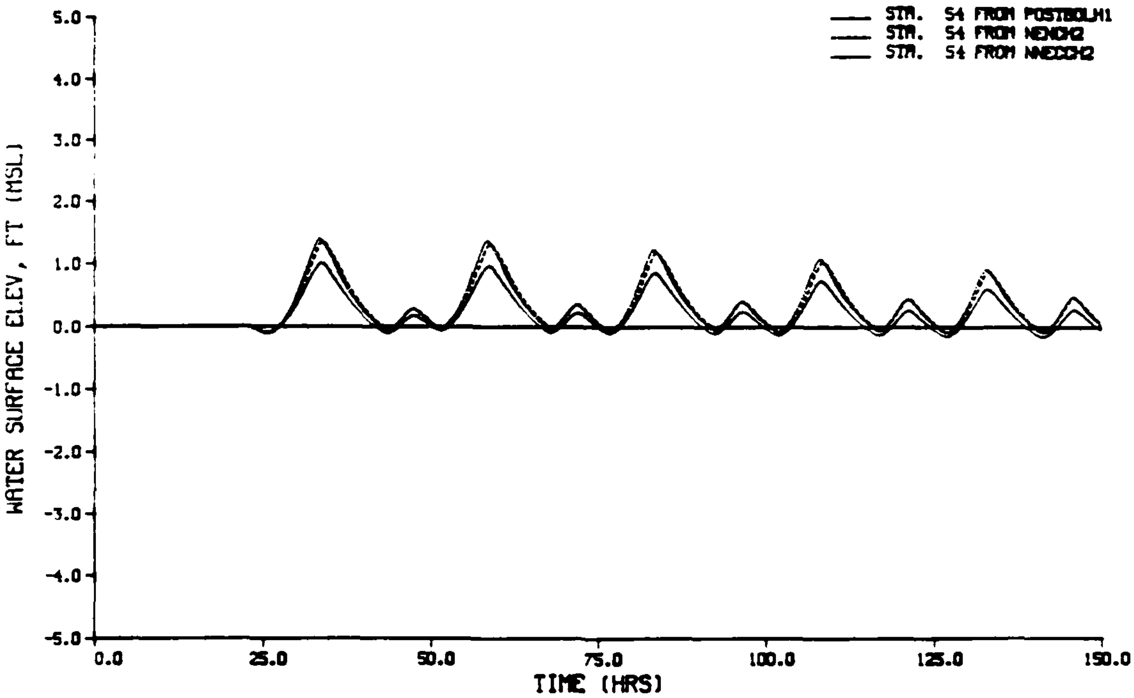


Figure 171. DFG cell, wetlands not connected, POSTBOL - existing condition, NENCH2 - navigable entrance, navigable channel to Huntington Harbour, NNECCH2 - non-navigable entrance and channel to Huntington Harbour

Velocities

179. Because the channels of Huntington Harbour are fairly large relative to those of Outer Bolsa Bay, average channel velocities through the harbor for non-navigable entrance channel conditions closely approximate those of the existing condition (Figures 172 through 174). The navigable entrance channel with a navigable connector channel to Huntington Harbour allows a greater amount of flow to enter Huntington Harbour from Outer Bolsa Bay, and a region of reduced average channel velocities is created in the harbor. However, because other factors are prevalent in the area (wind stresses, non-uniform tide conditions, non-linear boundary friction effects, etc.), a stagnation zone should not become established. Effects of reduced average channel velocities should have minimal impact on water parcel residence times.

180. Since Warner Avenue bridge will be relocated under all plan conditions (except for the navigable entrance with a non-navigable connector channel to Huntington Harbour concept), and the channel in this vicinity will

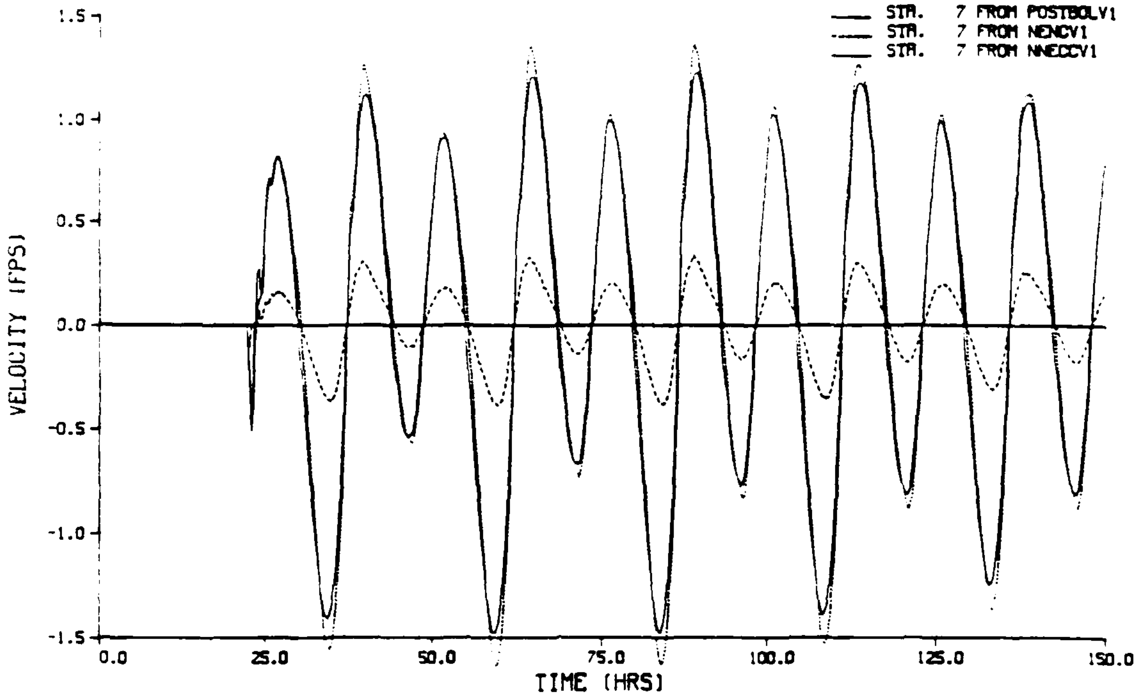


Figure 172. Huntington Harbour, POSTBOL - existing condition, NENCV1 - navigable entrance, navigable channel to Huntington Harbour, NNECCV1 - non-navigable entrance and channel to Huntington Harbour

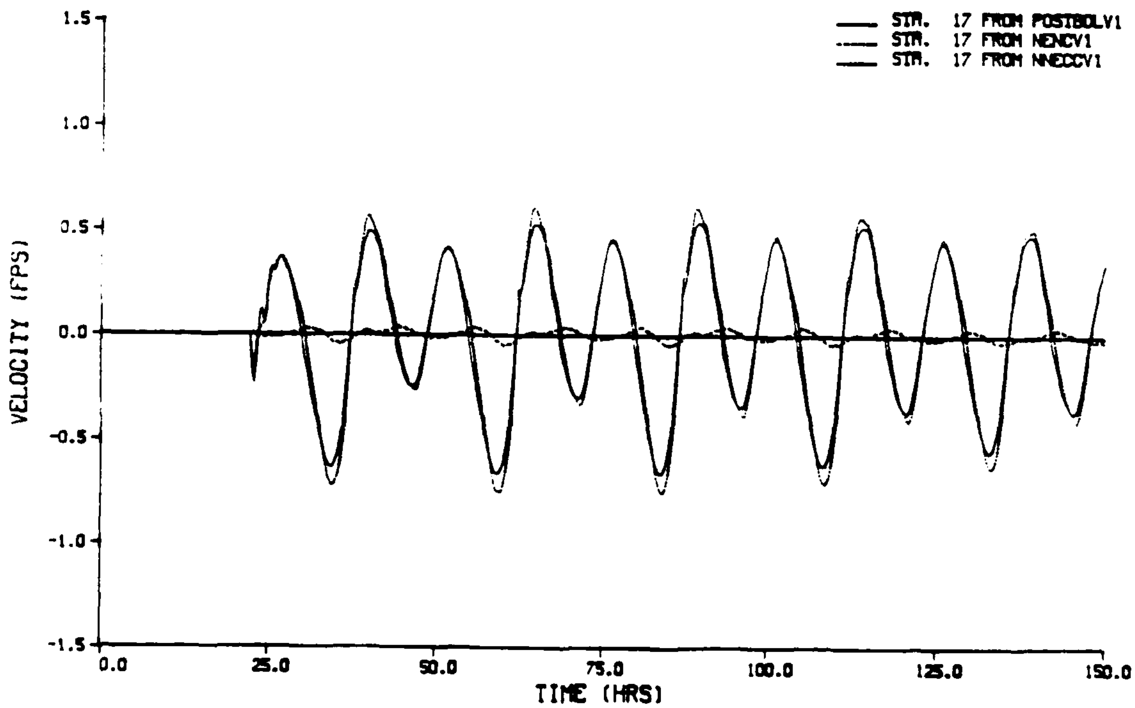


Figure 173. Huntington Harbour, POSTBOL - existing condition, NENCV1 - navigable entrance, navigable channel to Huntington Harbour, NNECCV1 - non-navigable entrance and channel to Huntington Harbour

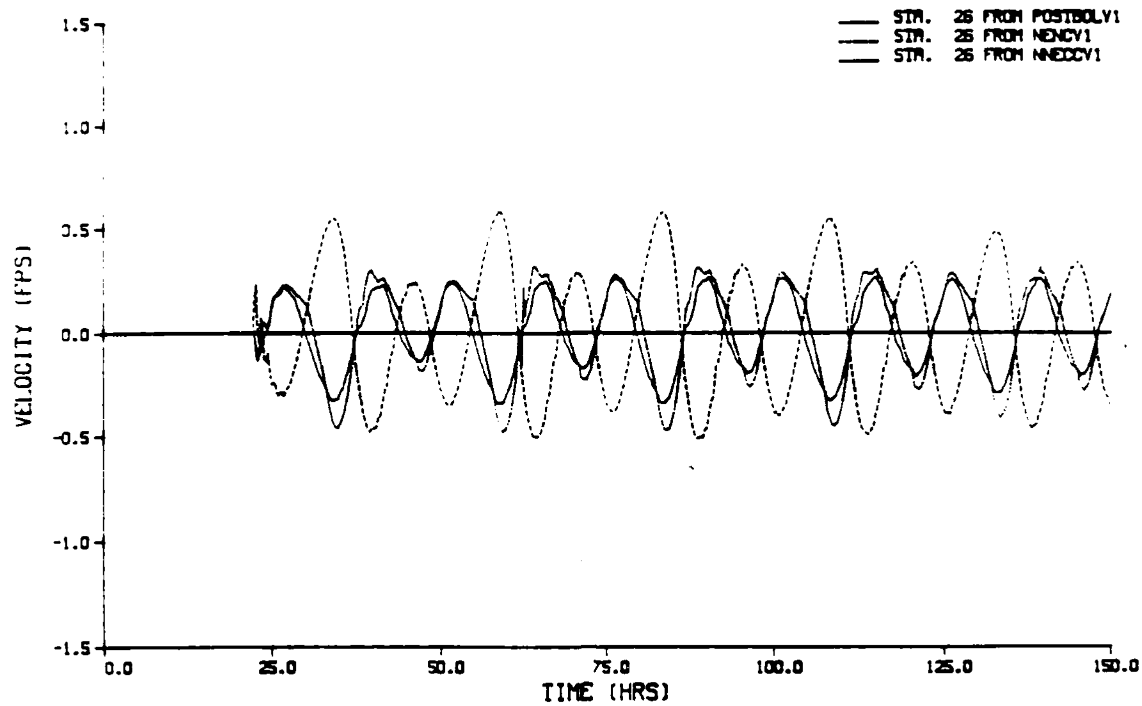


Figure 174. Huntington Harbour, POSTBOL - existing condition, NENCV1 - navigable entrance, navigable channel to Huntington Harbour, NNECCV1 - non-navigable entrance and channel to Huntington Harbour

be significantly enlarged, a comparison of velocities at this region (Link 34) may not be meaningful. Average channel velocities will be significantly reduced at this location for all plans (Figure 175).

181. Velocities in Outer Bolsa Bay under the two principal plan conditions respond essentially inversely to the tidal elevations (Figure 176). The significantly larger navigable connector channel to Huntington Harbour reduces the average channel velocities to a large extent, while the non-navigable entrance channel concept provides a more efficient hydraulic entrance and exit for tidal prism flow from the wetlands, thus reducing the maximum ebb velocities through Outer Bolsa Bay from that existing under present conditions.

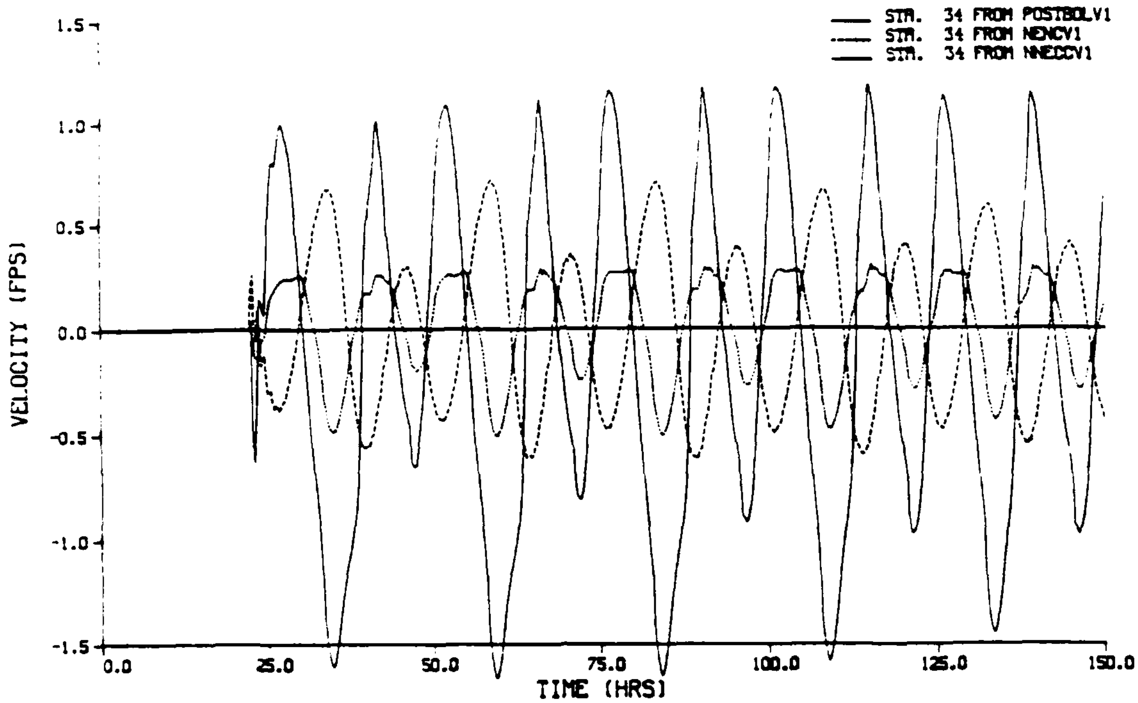


Figure 175. At Warner Avenue bridge, POSTBOL - existing condition, NENCV1 - navigable entrance, navigable channel to Huntington Harbour, NNECCV1 - non-navigable entrance and channel to Huntington Harbour

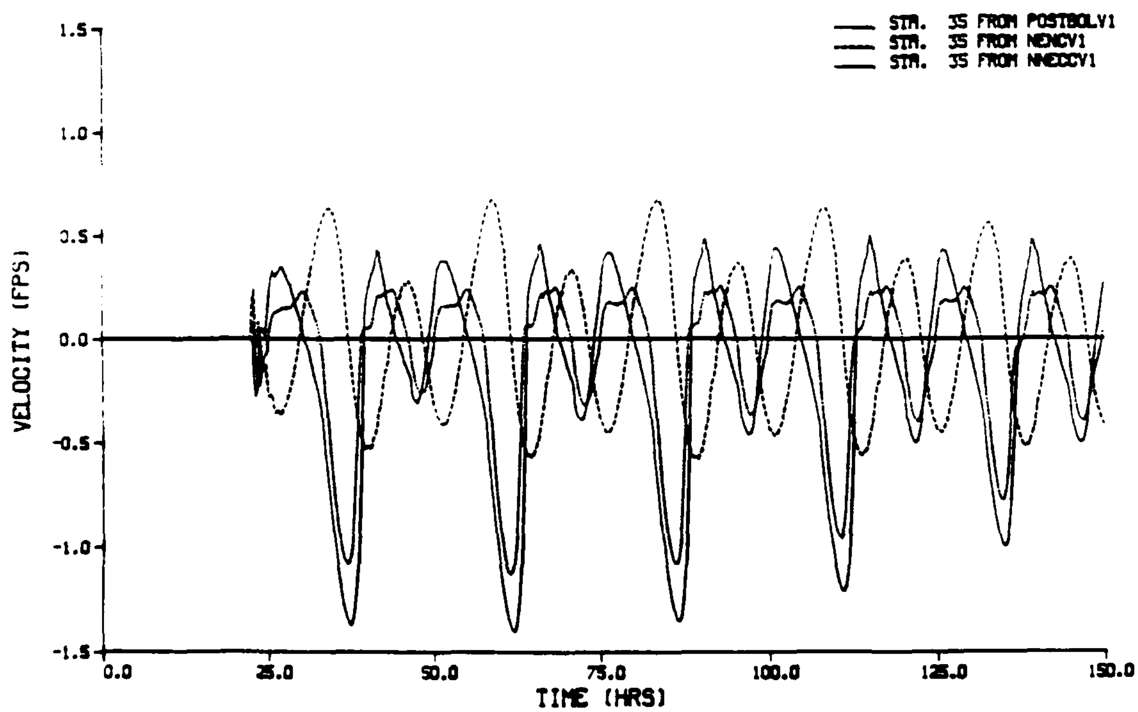


Figure 176. Outer Bolsa Bay, POSTBOL - existing condition, NENCV1 - navigable entrance, navigable channel to Huntington Harbour, NNECCV1 - non-navigable entrance and channel to Huntington Harbour

NENC versus NNECC versus NOENT
Comparison of Navigable Entrance with Non-Navigable and No Entrance Channel

Tidal elevations

182. Tidal elevation comparisons for the conditions of navigable entrance, non-navigable entrance, and non-navigable entrance closed by littoral material, are presented in Figure 177 for Huntington Harbour, and Figure 178 for Outer Bolsa Bay. Huntington Harbour tidal elevations are well known, responding as the ocean tide for all proposed alternative plans. For the non-navigable entrance, a portion of the tidal prism of the new wetlands is permitted to flow to the ocean through this outlet. Conversely, when the non-navigable entrance closes, all the wetland tidal prism is required to traverse through Outer Bolsa Bay. This condition is analogous to the existing condition with the exception that the volume of flow is exceedingly greater with the installation of the proposed new wetland enhancement. Hence, the low water tidal elevation is retained at a much higher level than for either the navigable entrance with a navigable connector channel to Huntington Harbour

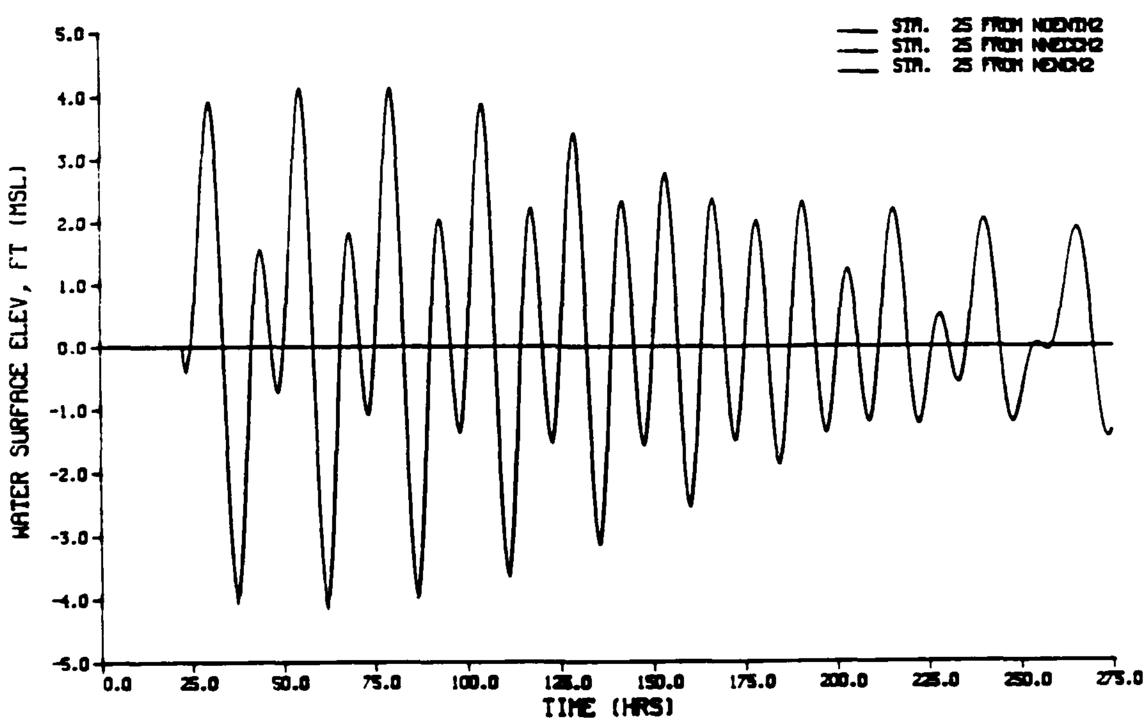


Figure 177. Huntington Harbour, NOENTH2 - entrance channel closed, NNECCH2 - non-navigable entrance and channel to Huntington Harbour, NENCH2 - navigable entrance, navigable channel to Huntington Harbour

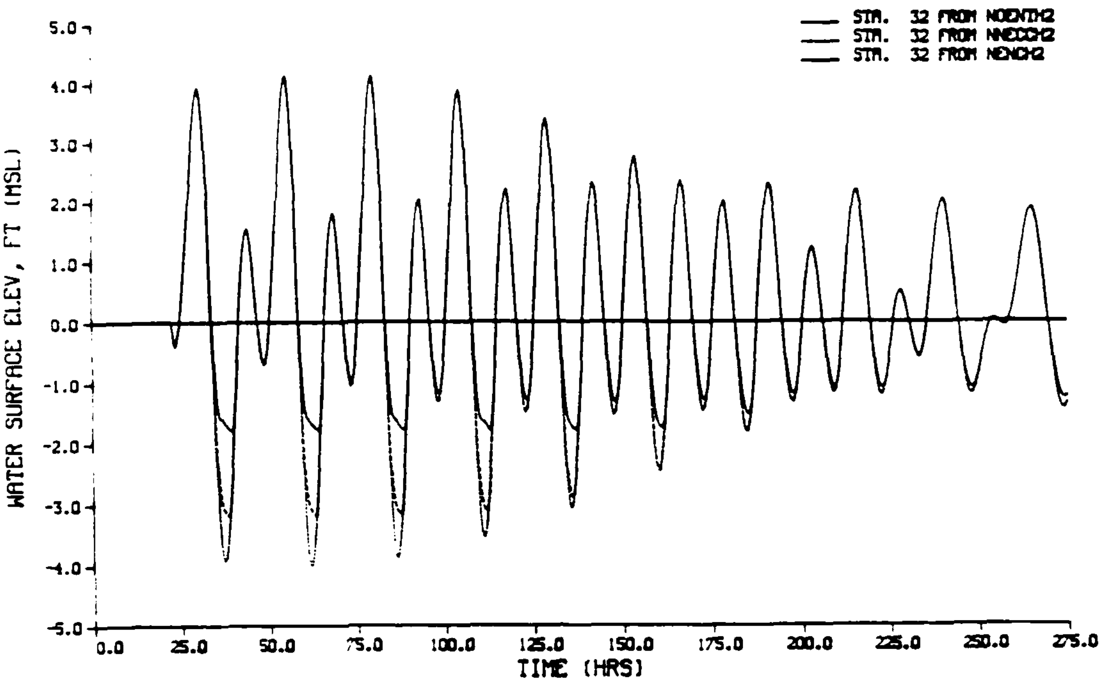


Figure 178. Outer Bolsa Bay, NOENTH2 - entrance channel closed, NNECCH2 - non-navigable entrance and channel to Huntington Harbour, NENCH2 - navigable entrance, navigable channel to Huntington Harbour

concept, or the non-navigable entrance with Outer Bolsa Bay remaining in its present condition. For all of the three scenarios under consideration, tidal elevations in Inner Bolsa Bay and the DFG muted tidal cell are approximately identical, being about 30 percent greater than existing conditions when Inner Bolsa Bay is assumed to not be connected to the proposed new muted tidal wetland enhancement area (Figures 179 and 180).

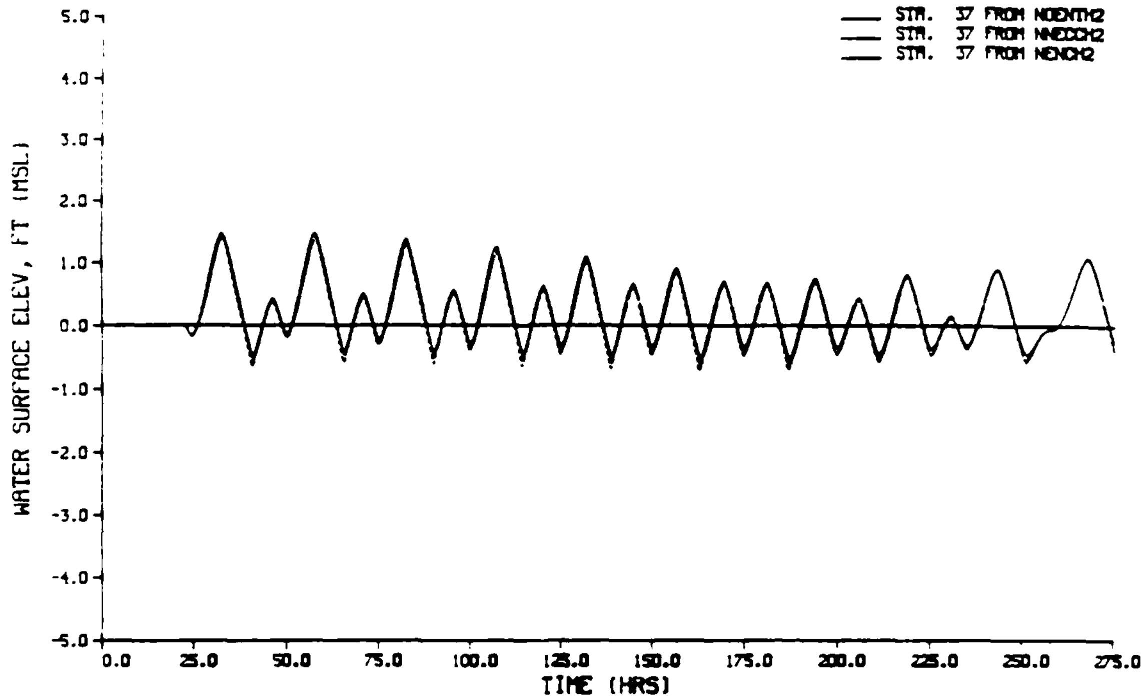


Figure 179. Inner Bolsa Bay, wetlands not connected, NOENTH2 - no entrance, NNECCH2 - non-navigable entrance and channel to Huntington Harbour, NENCH2 - navigable entrance, navigable channel to Huntington Harbour

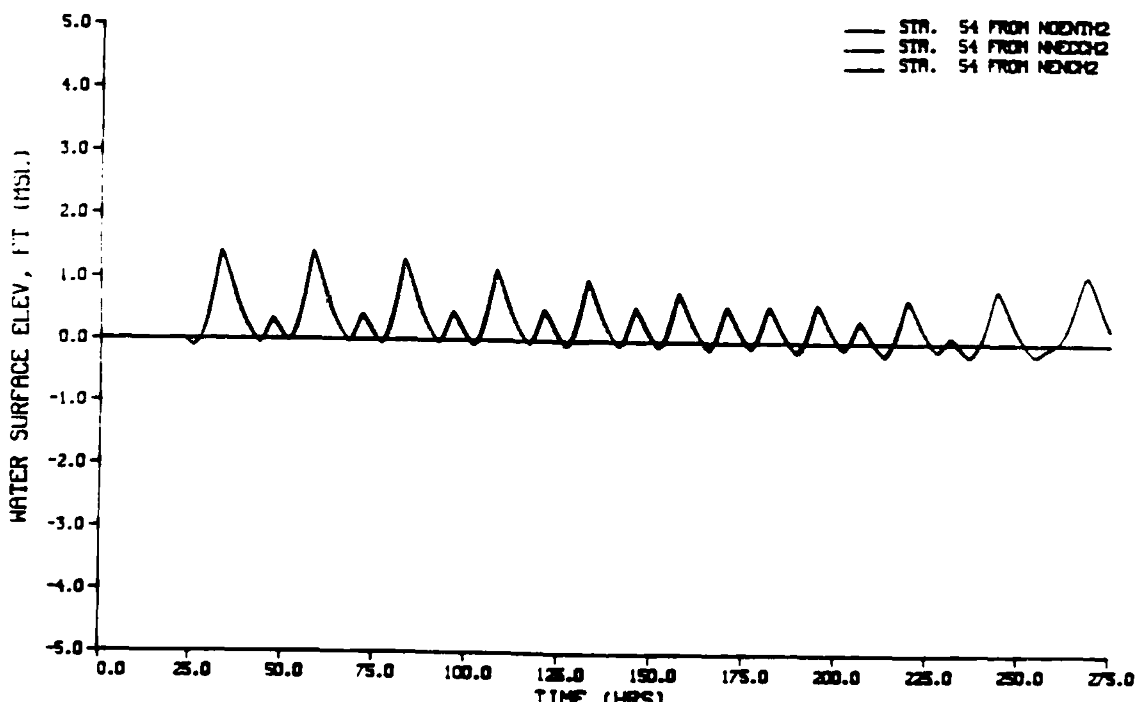


Figure 180. DFG muted cell, wetlands not connected, NOENTH2 - no entrance, NNECCH2 - non-navigable entrance and channel to Huntington Harbour, NENCH2 - navigable entrance, navigable channel to Huntington Harbour

Velocities

183. Here again, average channel velocities are not exceedingly different in Huntington Harbour except for the navigable entrance channel with a navigable connector channel to the harbor (Figure 181 through 183). The other two scenarios of non-navigable entrance channel and non-navigable entrance channel closed induce about the same magnitude of average channel velocities in the harbor because of the relative large channels in this region. Reduced average channel velocities in some portions of the harbor result from filling of the harbor by flows from both Anaheim Bay and Outer Bolsa Bay.

184. Because the channel at present Warner Avenue is proposed to be relocated and modified extensively in the navigable entrance with a navigable connector channel to Huntington Harbour concept, and in the non-navigable entrance channel concept, velocities will remain relatively moderate even when the non-navigable entrance channel closes by littoral material (Figure 184). Velocities in Outer Bolsa Bay, however, may reach up to 2.5 ft per sec

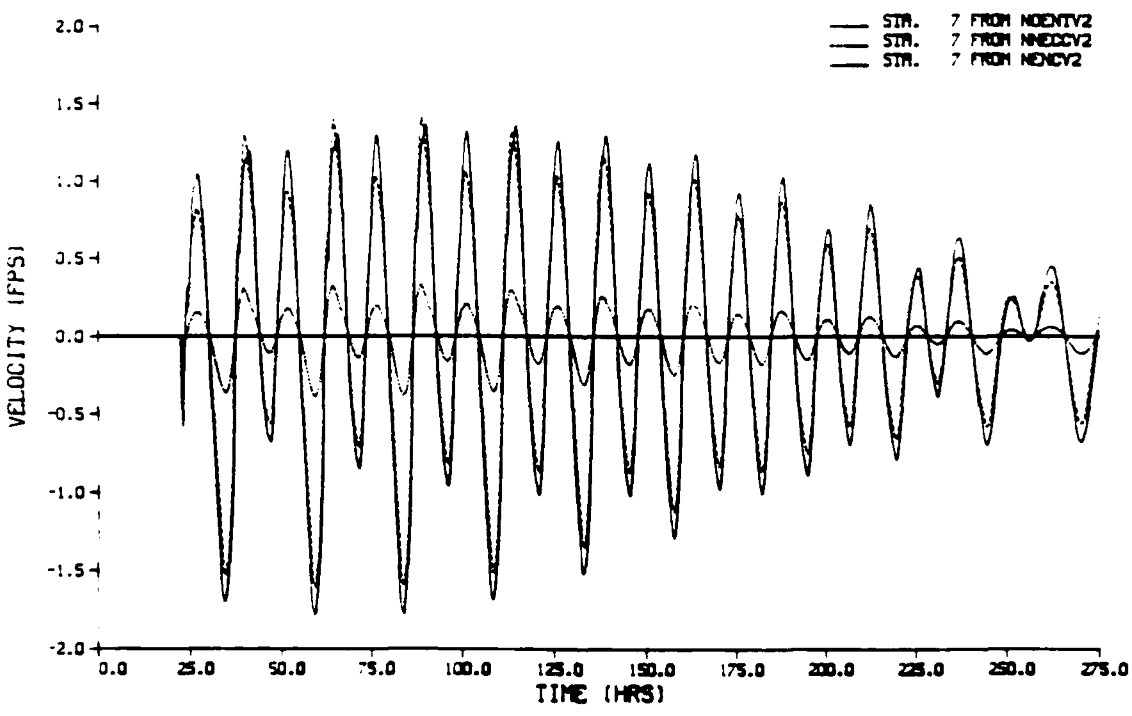


Figure 181. Huntington Harbour, NOENTV2 - entrance channel closed, NNECCV2 - non-navigable entrance and channel to Huntington Harbour, NENCV2 - navigable entrance, navigable channel to Huntington Harbour

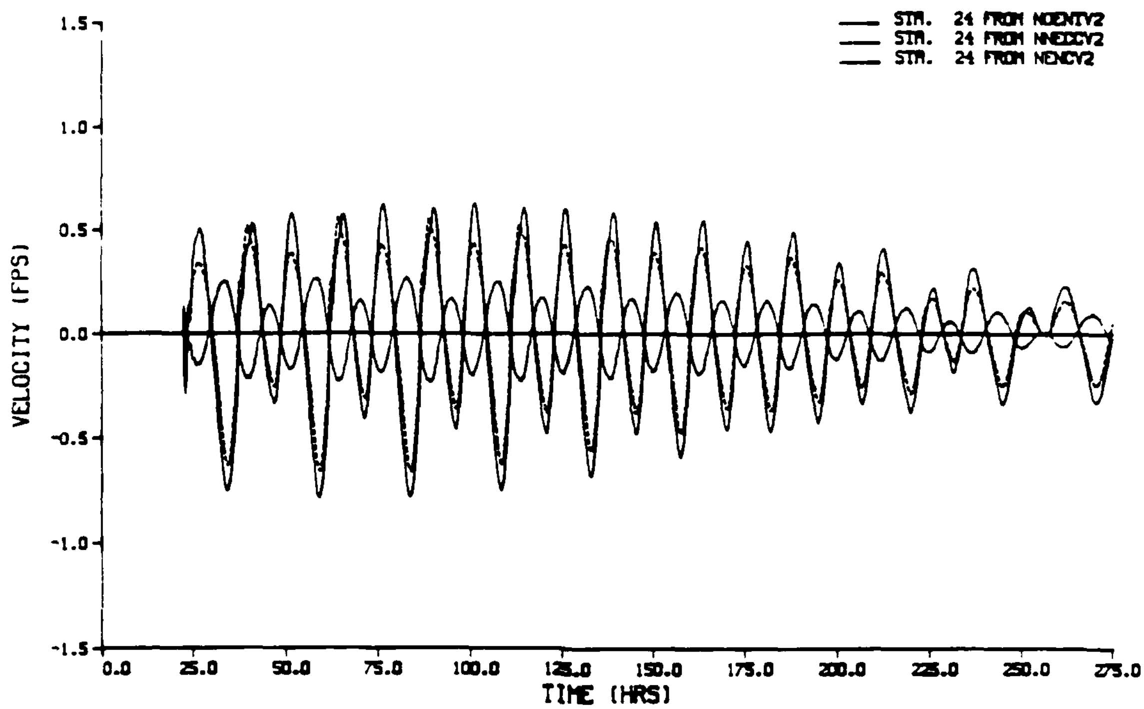


Figure 182. Huntington Harbour, NOENTV2 - entrance channel closed, NNECCV2 - non-navigable entrance and channel to Huntington Harbour, NENCV2 - navigable entrance, navigable channel to Huntington Harbour

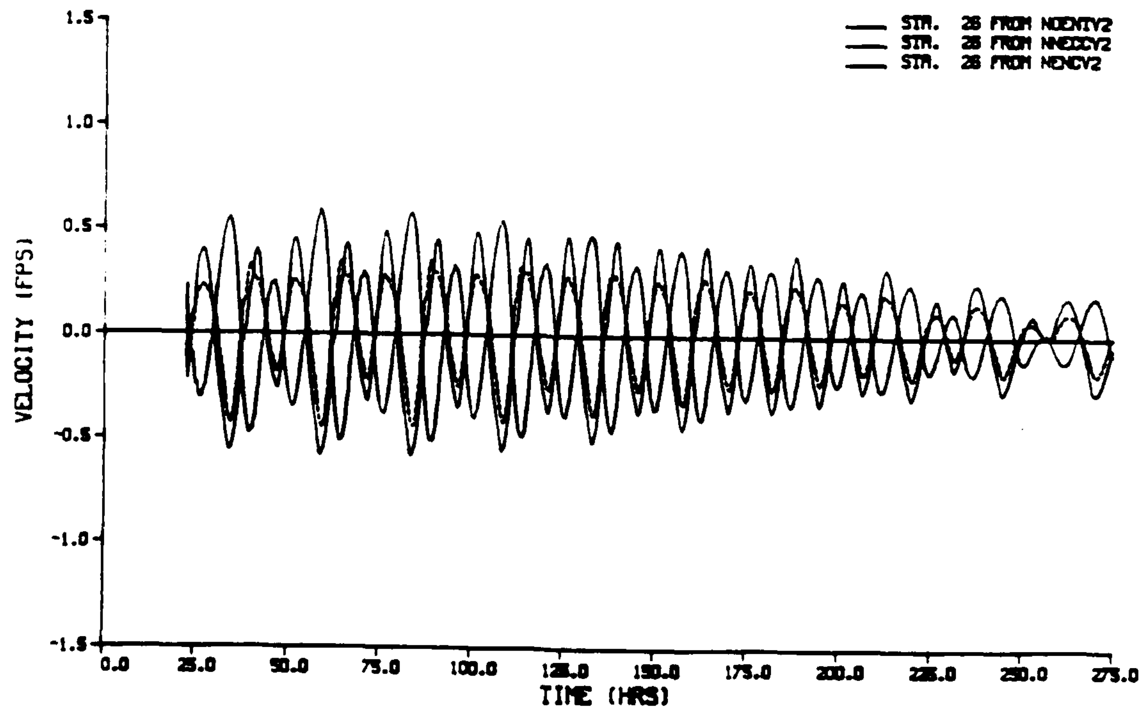


Figure 183. Huntington Harbour, NOENTV2 - entrance channel closed, NNECCV2 - non-navigable entrance and channel to Huntington Harbour, NENCV2 - navigable entrance, navigable channel to Huntington Harbour

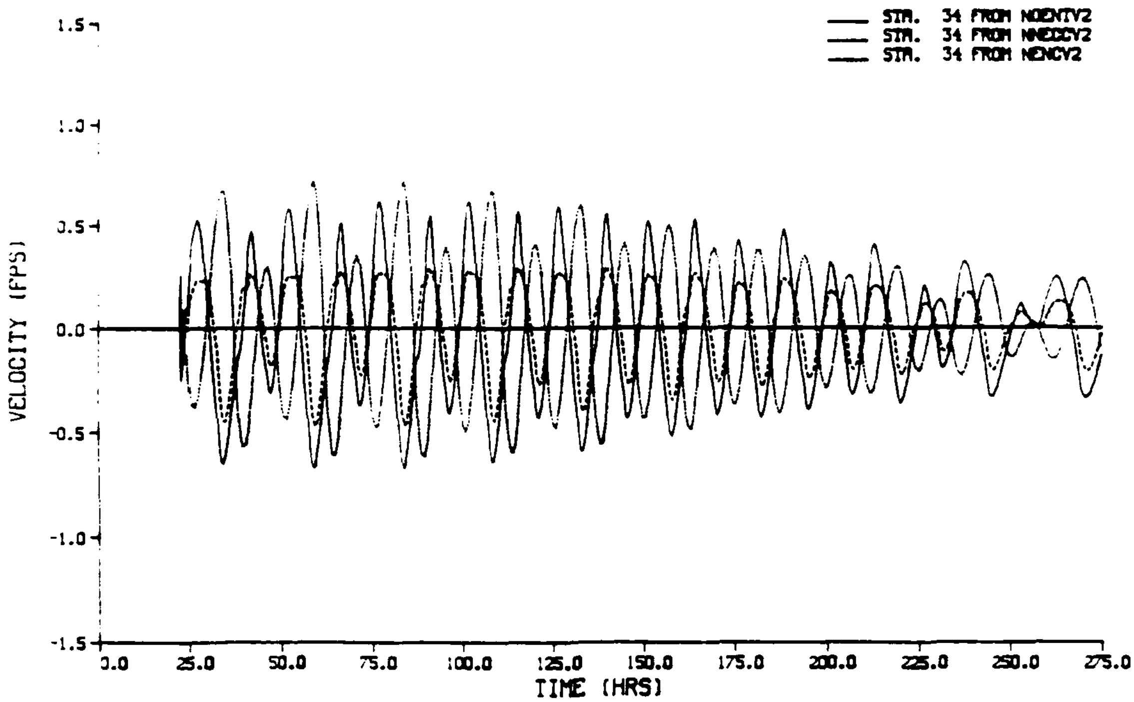


Figure 184. At Warner Avenue bridge, NOENTV2 - entrance channel closed, NNECCV2 - non-navigable entrance and channel to Huntington Harbour, NENCV2 - navigable entrance, navigable channel to Huntington Harbour

during ebb flow in a portion of the bay if the non-navigable entrance channel closes (Figure 185). These velocity increases are induced by the large tidal prism required by the proposed new wetland enhancement area which must pass entirely through the Outer Bolsa Bay. Such velocities may scour sediments from the bay as this material consists of silty sands and clayey sands (Woodward-Clyde Consultants 1987). However, the non-navigable entrance could be reopened immediately following a storm to alleviate potential scouring velocities in Outer Bolsa Bay. Potential scour in Outer Bolsa Bay could be prevented by various channel stabilization measures provided as part of project construction.

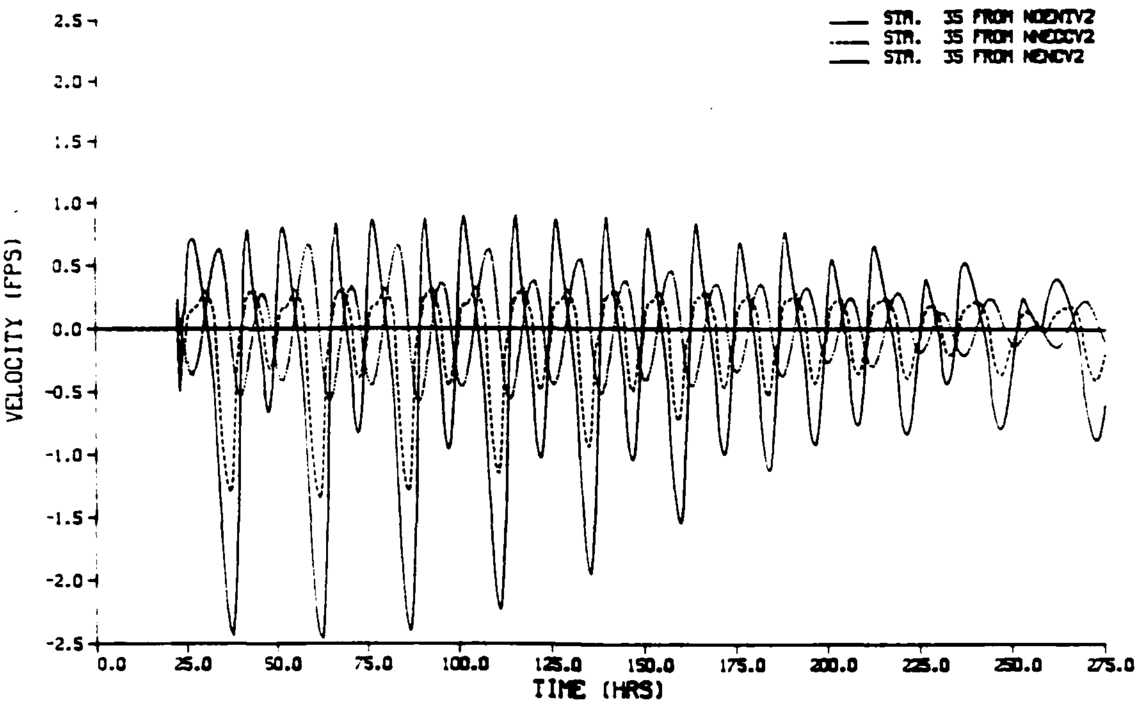


Figure 185. Outer Bolsa Bay, NOENTV2 - entrance channel closed, NNECCV2 - non-navigable entrance and channel to Huntington Harbour, NENCV2 - navigable entrance, navigable channel to Huntington Harbour

PART X: EAST GARDEN GROVE-WINTERSBURG FLOOD CONTROL CHANNEL (EGG-WFCC) 100-YEAR FLOOD FLOW

185. The hydrograph for the 100-year frequency of occurrence flood for the EGG-WFCC watershed has been developed by Moffatt & Nichol, Engineers (1986b), based on hydrology guidance provided by the Orange County Flood Control District (1986). The peak flow rate for the 100-year flood was determined to be 9,710 cfs. This estimated 100-year peak flow rate is 23 percent higher than the 1977 estimate, and is the result of improved hydraulic data presently utilized by the County of Orange. The lower reaches of the existing earthen-lined WFCC can presently convey only approximately 65 percent of a 25-year storm. It is assumed that the channel will be improved upstream of the Bolsa Bay project to a 100-year storm runoff capacity.

Tidal Elevations

186. Concern exists regarding the maximum flood flow elevations which may be reached in Huntington Harbour, the proposed marina, and the wetlands by the 100-year flood, for both existing conditions and various alternative proposed plans for wetland enhancement. Levee elevations with adequate free-board must be established to preclude overtopping. It is considered that all culvert systems will function during flood conditions in the same manner as during normal tidal cycles; i.e., the culverts will not be closed to prevent flood flow from entering the wetlands.

187. Accordingly, the 100-year flood flow (9,710 cfs) was introduced through the flood control gates on the EGG-WFCC at the appropriate alternative plan location. The numerical model was operated for 3 days under simultaneous spring tide and flood flow conditions. While the peak flow rate will last only a few hours, the 3-day model simulation was performed to observe maximum dynamic equilibrium elevations which would develop in the wetlands. Maximum water surface elevations for existing conditions and alternative plans are displayed in Figures 186 through 195 for representative locations through the Bolsa Bay system.

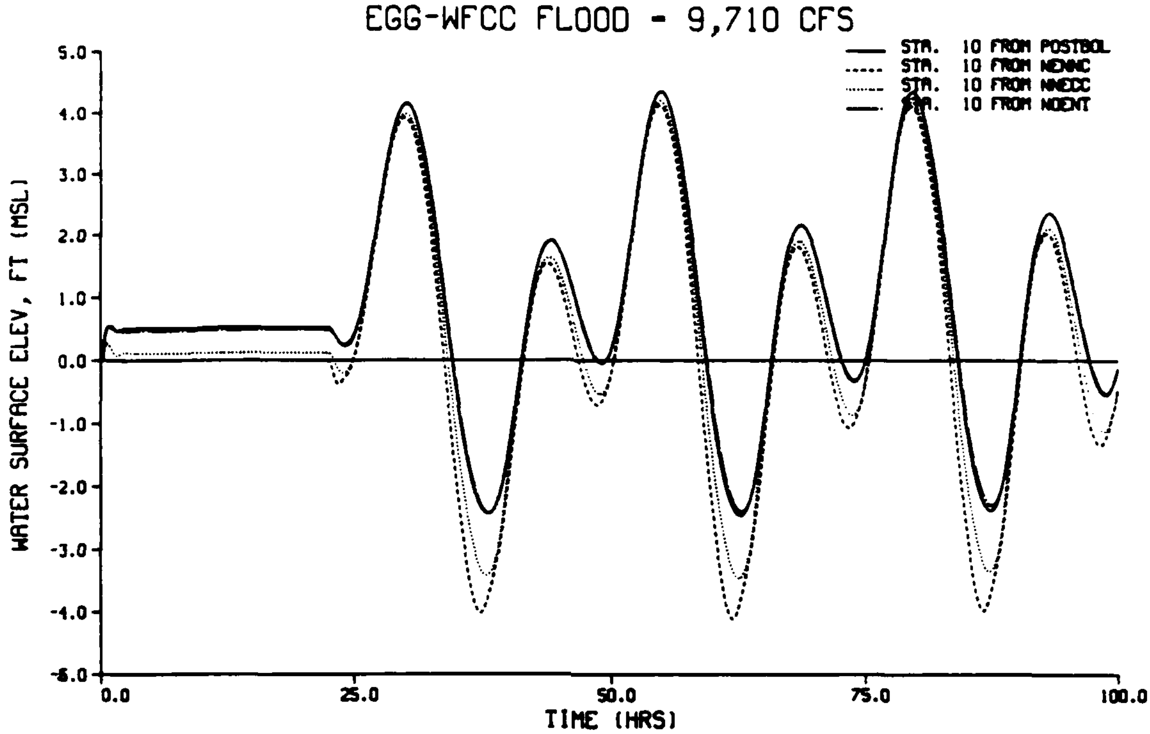


Figure 186. Water surface elevations in Huntington Harbour, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

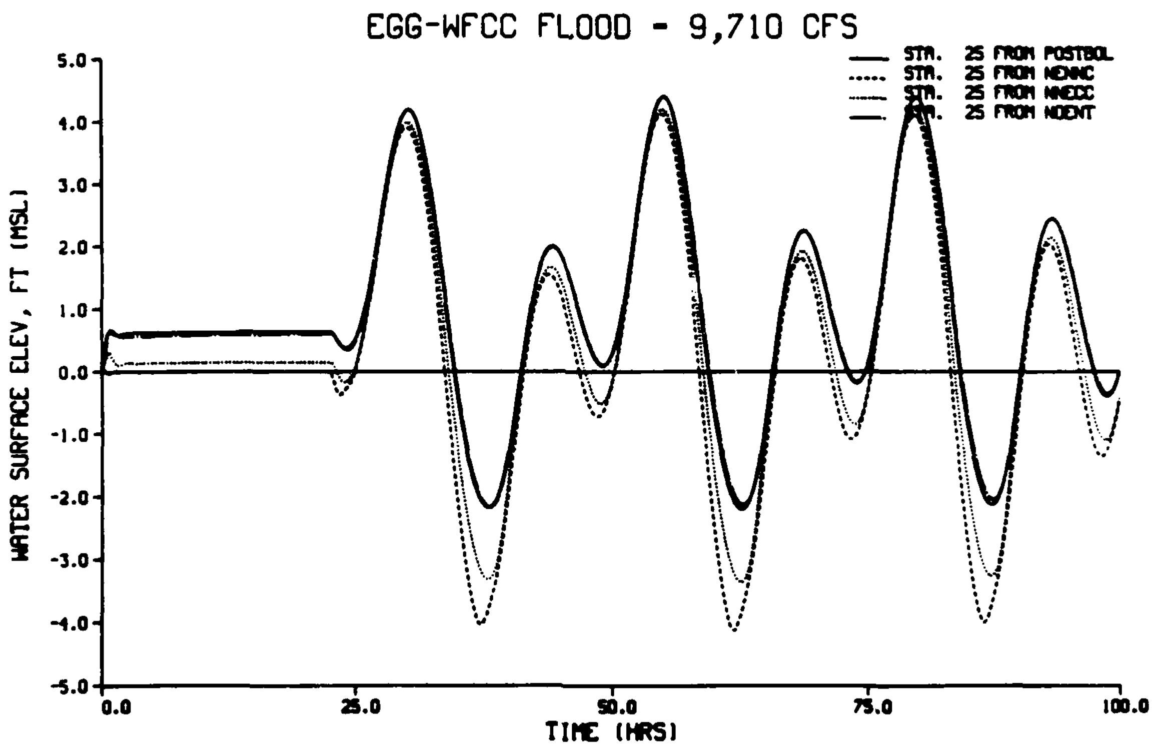


Figure 187. Water surface elevations in Huntington Harbour, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

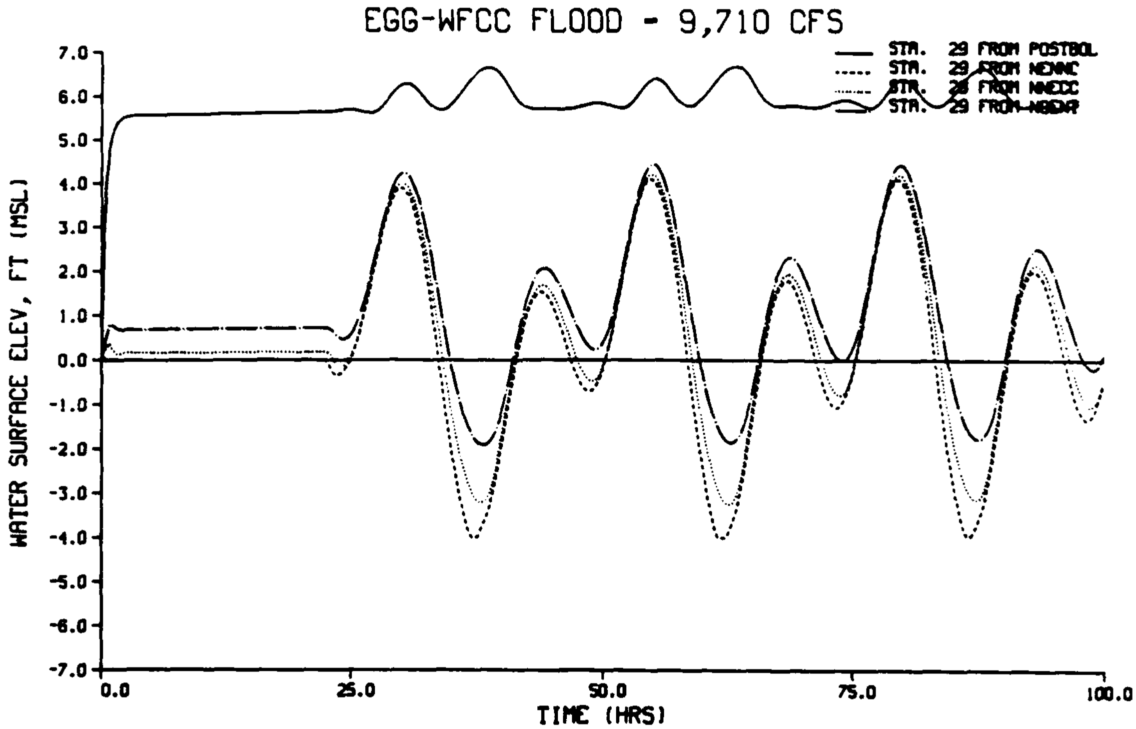


Figure 188. Water surface elevations in Outer Bolsa Bay, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

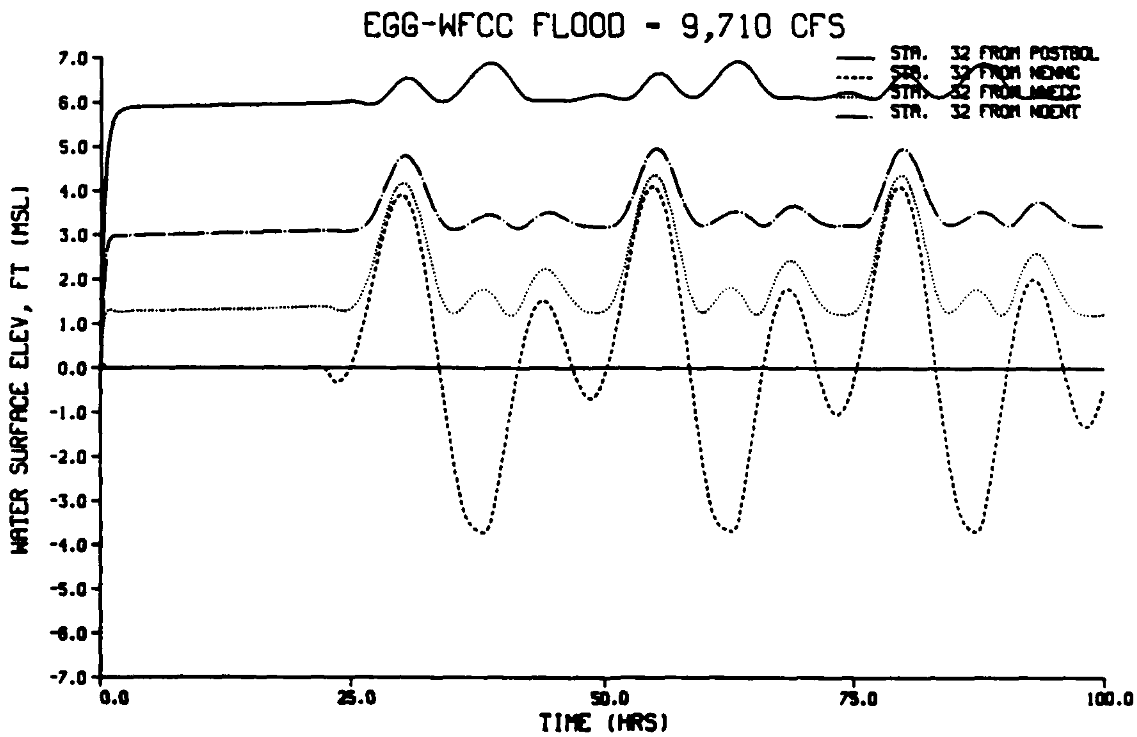


Figure 189. Water surface elevations in Outer Bolsa Bay, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

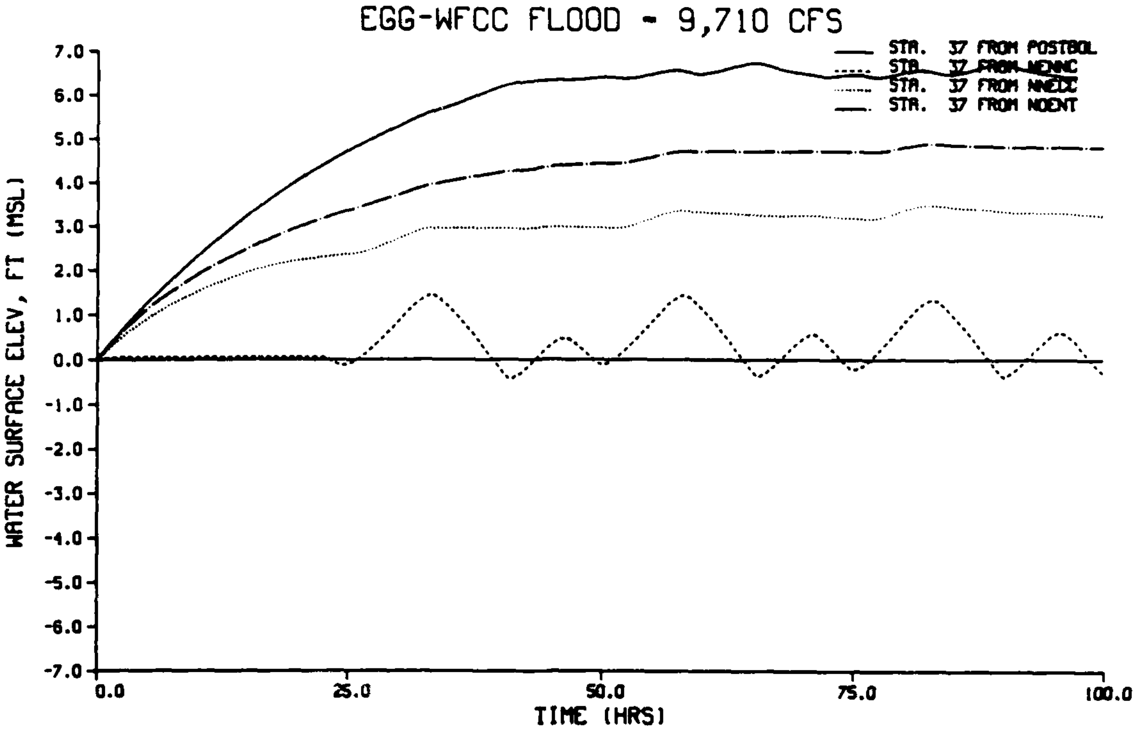


Figure 190. Water surface elevations in Inner Bolsa Bay, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

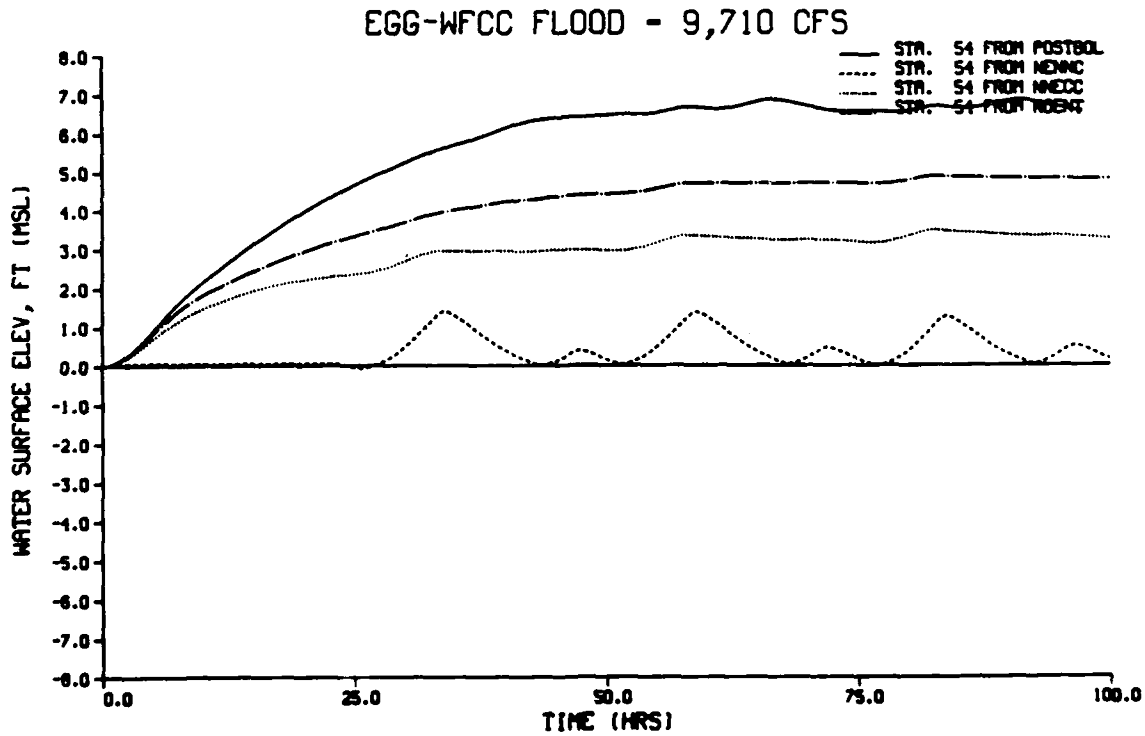


Figure 191. Water surface elevations in DFG muted tidal cell, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

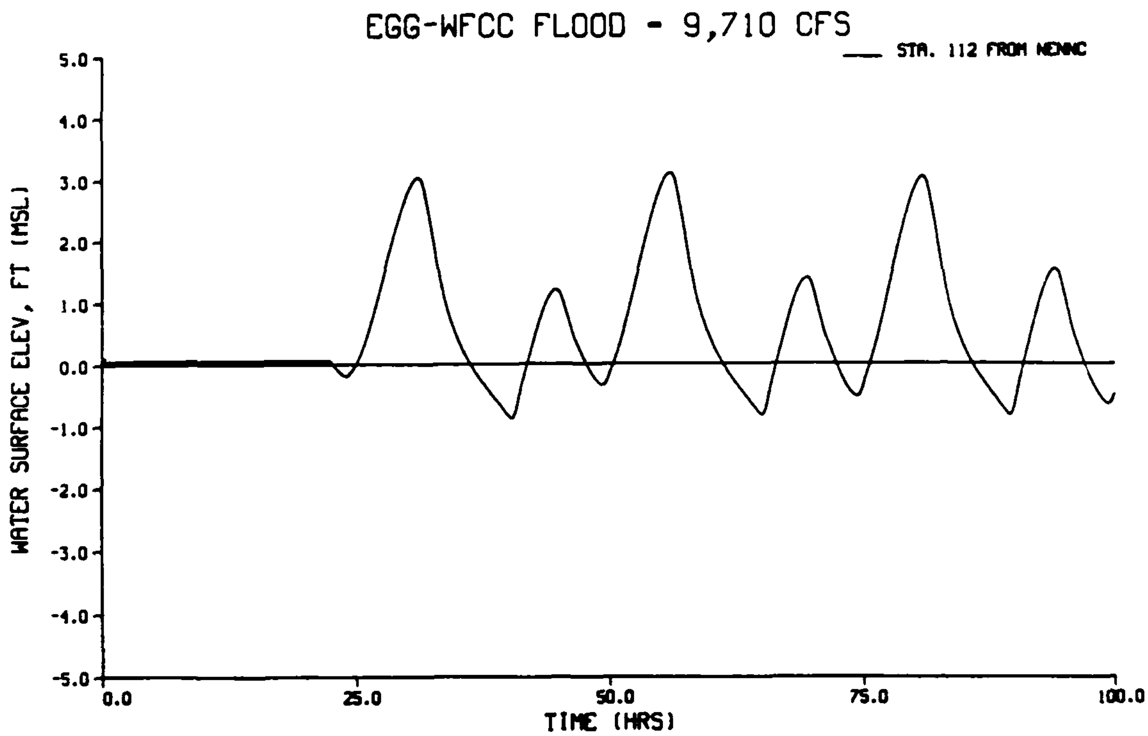


Figure 192. Water surface elevations in proposed full tidal wetlands, NENNC - navigable entrance channel

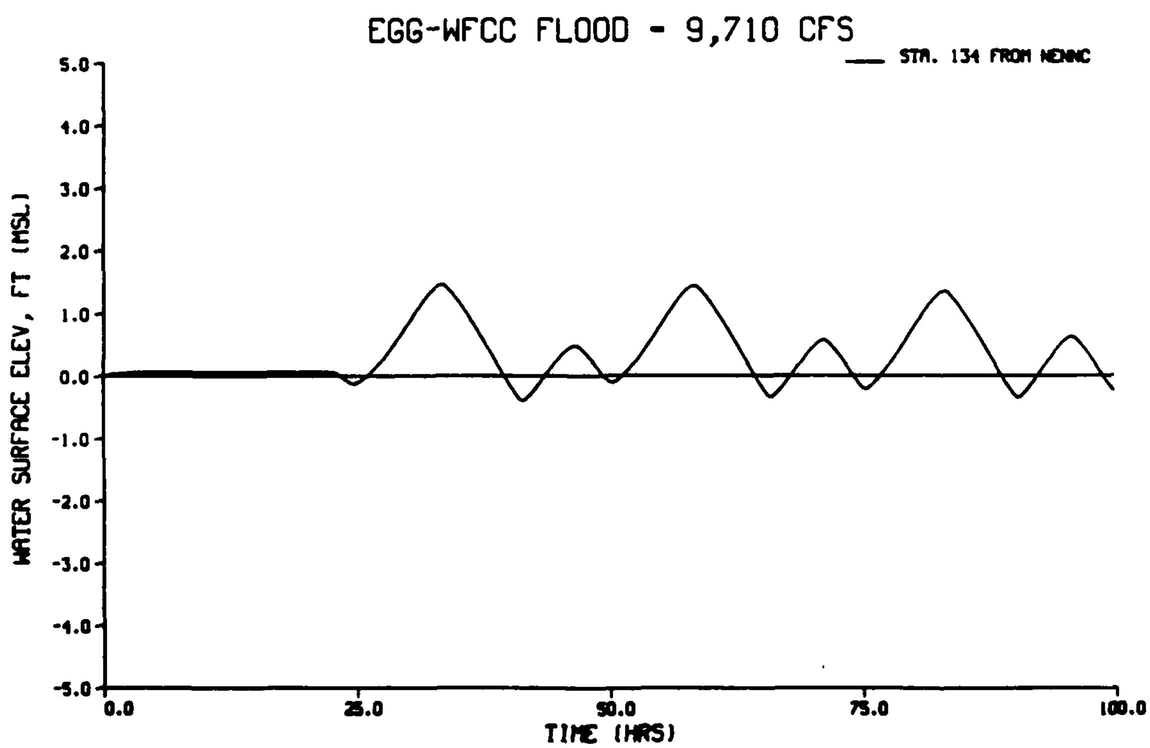


Figure 193. Water surface elevations in proposed muted tidal wetlands, NENNC - navigable entrance channel

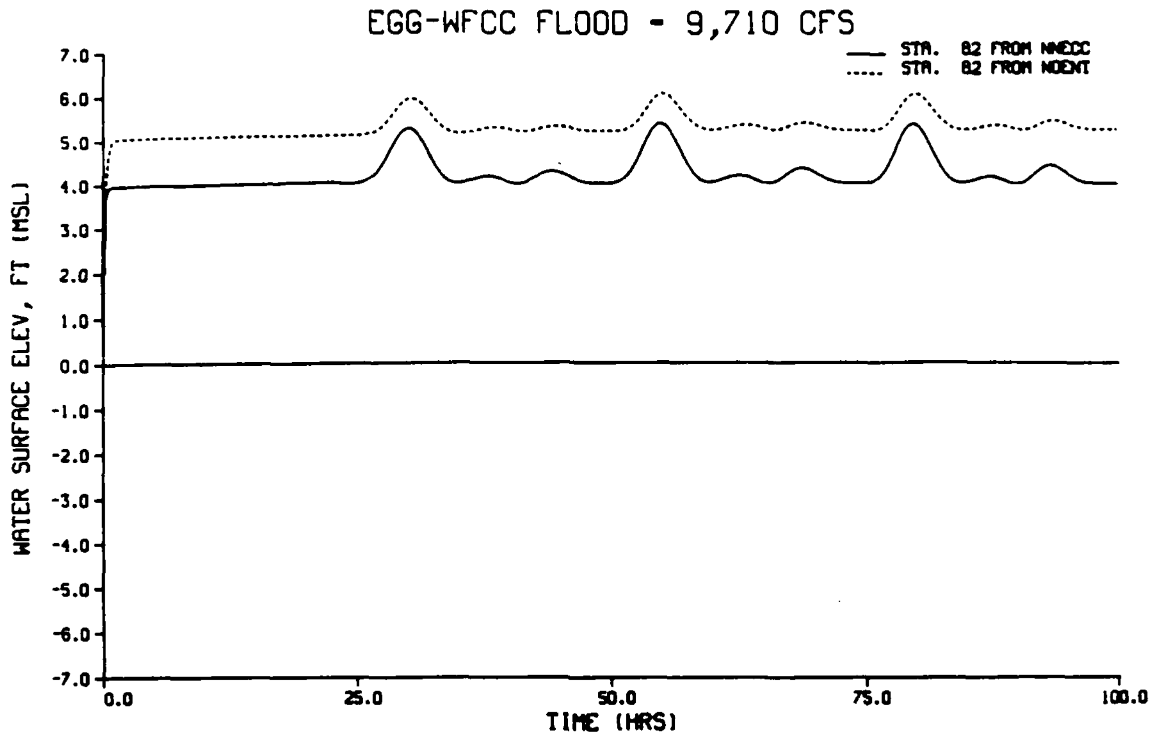


Figure 194. Water surface elevations at EGG-WFCC flood gates, NNECC - non-navigable entrance channel, NOENT - no entrance channel

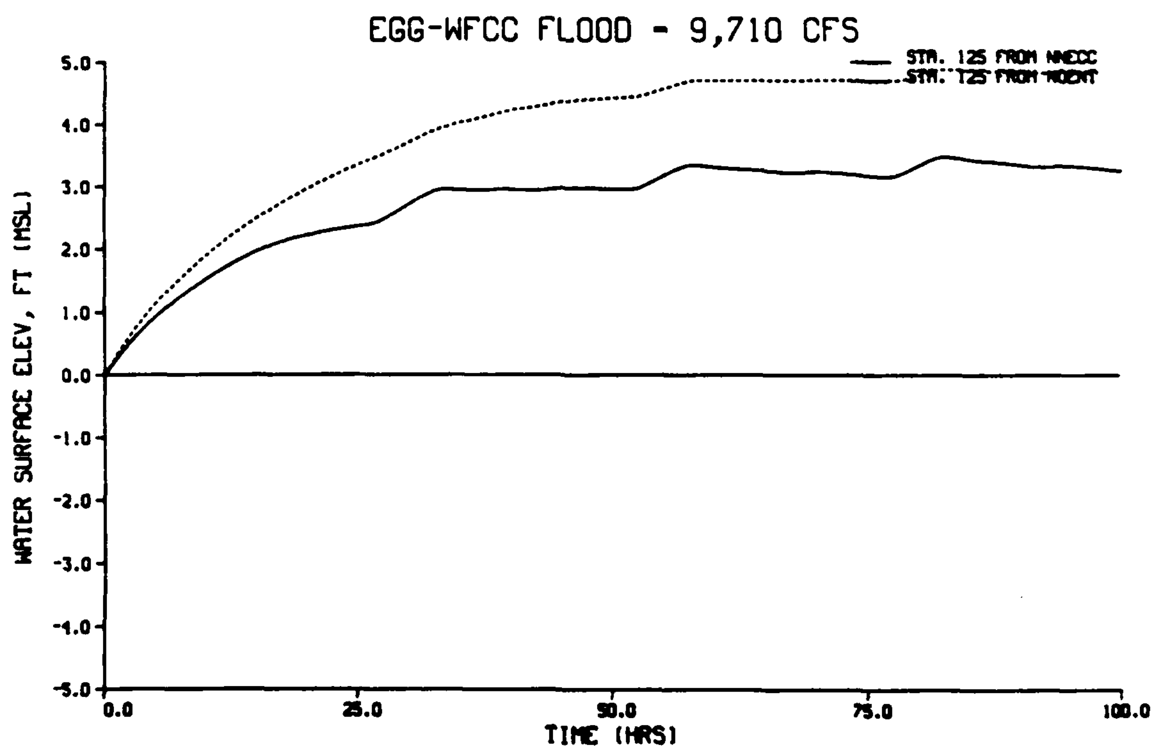


Figure 195. Water surface elevations in proposed muted tidal wetlands, NNECC - non-navigable entrance channel, NOENT - no entrance channel

Existing conditions

188. Under existing conditions, all flood flow is required to pass through Outer Bolsa Bay and Huntington Harbour. Warner Avenue bridge acts as an effective restriction to the passage of the 100-year flood discharge, flow is retarded by the bridge constriction, and ponding occurs in Outer Bolsa Bay at a dynamic equilibrium elevation determined by the hydraulic characteristics of the system. The maximum water surface achieved in Outer Bolsa Bay was 7.1 ft msl, an increase beyond the normal spring high tide elevation of about 3.0 ft, from 4.1 ft to 7.1 ft (Figures 188 and 189).

189. Because of the elevated water surfaces in Outer Bolsa Bay, flooding of Inner Bolsa Bay occurs, where the maximum water surface elevation increases to around 6.7 ft from 1.0 ft, an increase over normal spring high tide elevations of about 5.7 ft (Figure 190). A similar increase in water surface elevation is achieved in the DFG muted tidal cell (Figure 191).

190. Damping created by Warner Avenue bridge prevents most undulations of tidal activity existing in Huntington Harbour from propagating upstream into Outer Bolsa Bay. Thus, the bridge opening allows the passage of a quantity of flow that can be effectively transmitted through the harbor. The wide, highly efficient conveyance channels of the harbor allow the passage of the flood flow with only minimal increase in maximum water surface elevation, this value being about 0.3 ft, from 4.1 ft to 4.4 ft (Figures 186 and 187). There results a hydraulic drop across Warner Avenue bridge of about 2.3 ft, from 6.6 ft to 4.4 ft. Maximum water surface elevations for existing conditions and alternative plans are tabulated in Table 17.

Navigable entrance, existing connector to Huntington Harbour

191. The 100-year flood flow of 9,710 cfs is insignificant with respect to the ability of the navigable entrance channel to convey the discharge. The flow will pass directly through the proposed marina and into the Pacific Ocean. Maximum water levels in Huntington Harbour and Outer Bolsa Bay will be unaffected. Inner Bolsa Bay will experience an increase in water surface elevation beyond normal spring tides of about 0.5 ft, from 1.0 ft to about 1.5 ft (50 percent increase). The DFG muted tidal cell maximum water surface elevation will increase about 0.4 ft, from 1.0 ft to about 1.4 ft (40 percent increase). Maximum water surface elevations in both the full tidal and muted tidal wetlands will increase only about 0.1 ft (Figures 192 and 193).

Table 17

Maximum Water Surface Elevations

Spring Tide plus 100-Year Flood Flow (9,710 cfs) in East Garden Grove-Wintersburg Flood Control Channel

Location	Node No	Elevation, feet (msl)				
		POSTBOL Spring	POSTBOL Flood	NENNC Flood	NNECC Flood	NOENT Flood
Huntington Harbour	10	4.10	4.35	4.11	4.19	4.34
Huntington Harbour	25	4.10	4.40	4.11	4.20	4.39
Outer Bolsa Bay	29	4.10	6.66	4.10	4.22	4.44
Outer Bolsa Bay	30	4.10	6.74	4.10	4.27	4.65
Outer Bolsa Bay	31	4.10	6.81	4.10	4.32	4.80
Outer Bolsa Bay	32	4.10	6.89	4.09	4.36	4.96
Outer Bolsa Bay	33	4.10	7.09	4.09	4.51	5.39
Inner Bolsa Bay	37	1.04	6.73	1.47	3.48	4.93
DFG muted tidal cell	54	0.98	6.85	1.41	3.48	4.93
EGG-WFCC	82	----	----	----	5.43	6.11
Channel to muted tidal wetlands	84	----	----	----	5.42	6.11
Proposed marina	89	----	----	4.13	----	----
Proposed full tidal wetlands	112	----	----	3.12	----	---
Proposed muted tidal wetlands	125	----	----	----	3.48	4.93
Proposed muted tidal wetlands	134	----	----	1.47	----	----

POSTBOL - existing conditions
NENNC - navigable entrance channel, with existing connection to Huntington Harbour
NNECC - non-navigable entrance channel, with existing connection to Huntington Harbour
NOENT - non-navigable entrance channel closed, with existing connection to Huntington Harbour

Non-navigable entrance, existing connector to Huntington Harbour

192. The non-navigable entrance channel and Warner Avenue bridge respond hydrodynamically to cause an increase in water surface slope along Outer Bolsa Bay from the bridge to the proposed new entrance. There results only about a 0.1 ft increase in maximum water surface elevation in Huntington Harbour, but an increase across Outer Bolsa Bay which varies from about 0.1 ft at Warner Avenue bridge to about 0.4 ft at the proposed new entrance. Inner Bolsa Bay and the DFG muted tidal cell will experience flooding, and an increase in maximum water surface elevation of about 2.5 ft, from about 1.0 ft to about 3.5 ft (250 percent increase). The proposed muted tidal wetlands will experience about a 2.4 ft increase in maximum water surface elevation, from about 1.1 ft to about 3.5 ft (220 percent increase).

Non-navigable entrance closed, existing connector to Huntington Harbour

193. If the non-navigable entrance channel is permitted to close by littoral material in the surf zone, a situation analogous to the existing condition will result, with the exception that the tidal prism has been significantly increased by muted tidal wetland enhancement. All flow will again be required to pass through Outer Bolsa Bay and Huntington Harbour. The harbor will experience an increase in maximum water surface elevation of about 0.3 ft, from 4.1 ft to 4.4 ft. Outer Bolsa Bay will experience a water surface profile across the bay of about 1.0 ft, from 4.4 ft at Warner Avenue bridge to about 5.4 ft at the previous non-navigable entrance location. Maximum water surface elevations in Outer Bolsa Bay will increase about 1.3 ft, from 4.1 ft to about 5.4 ft (30 percent increase).

194. Under these conditions, Inner Bolsa Bay and the DFG muted tidal cell will experience flooding with an increase in maximum water surface elevation greater than normal spring tides of about 3.9 ft, from 1.0 ft to 4.9 ft (390 percent increase). The proposed muted tidal wetlands also will flood to the same elevation of about 4.9 ft from about 1.0 ft under normal spring tide conditions.

Velocities

195. Maximum average channel velocities for the simultaneous occurrence of spring tide and the 100-year flood flow discharging into the Bolsa Bay

complex by the EGG-WFCC are presented in Figures 196 through 201 for representative locations throughout the system. These data are tabulated in Table 18. In analyzing these velocity magnitudes, particularly at Warner Avenue bridge, it is significant that the bridge is relocated and the channel greatly enlarged for all alternative plans (except for the navigable entrance channel with the existing connector to Huntington Harbour concept).

Existing conditions

196. Maximum average channel velocity increases throughout the Bolsa Bay system are non-linearly proportional to the water surface elevation increases. While the maximum water surface elevations throughout Huntington Harbour are not significantly greater under the 100-year flood flow conditions, maximum average channel velocities occur near mean tide elevations when the flow cross-sectional areas are less than maximum. Hence, the tidal flows and flood flows are being conveyed simultaneously through a minimum area and, thus, at a maximum velocity.

197. Maximum average channel velocities increase at the Pacific Coast Highway bridge from about 2.8 ft per sec to about 5.0 ft per sec (80 percent increase). Maximum average channel velocities in Huntington Harbour increase up to a maximum of 3.5 ft per sec from about 1.5 ft per sec (130 percent increase). Other sections experience a greater percentage increase, although not as large an absolute magnitude.

198. Warner Avenue bridge vicinity experiences excessively high velocities due to the large difference in water levels across the bridge. Maximum average velocities increase from about 1.6 ft per sec to about 11.6 ft per sec (600 percent increase). Outer Bolsa Bay will experience velocities approaching 2.8 ft per sec, which would be significantly greater if not for the damming effect created by Warner Avenue bridge.

Navigable entrance, existing connector to Huntington Harbour

199. This concept allows all flood flow to exit from the Bolsa Bay complex directly into the Pacific Ocean with minimal (imperceptible) hydrodynamic effects on the system. Velocities through Huntington Harbour and Outer Bolsa Bay are reduced below normal spring tide values (except for the link immediately adjacent to the proposed new entrance channel). From the hydrodynamic standpoint, this concept best and effectively reproduces the existing conditions through Huntington Harbour and Outer Bolsa Bay.

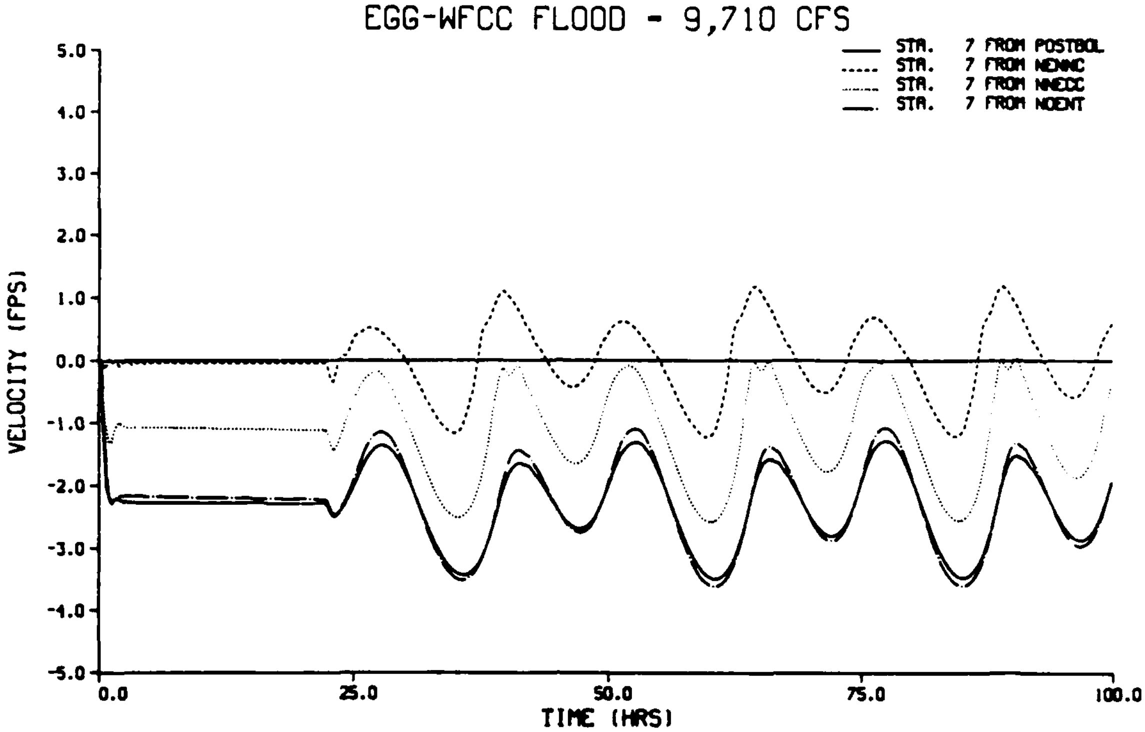


Figure 196. Average channel velocities in Huntington Harbour, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

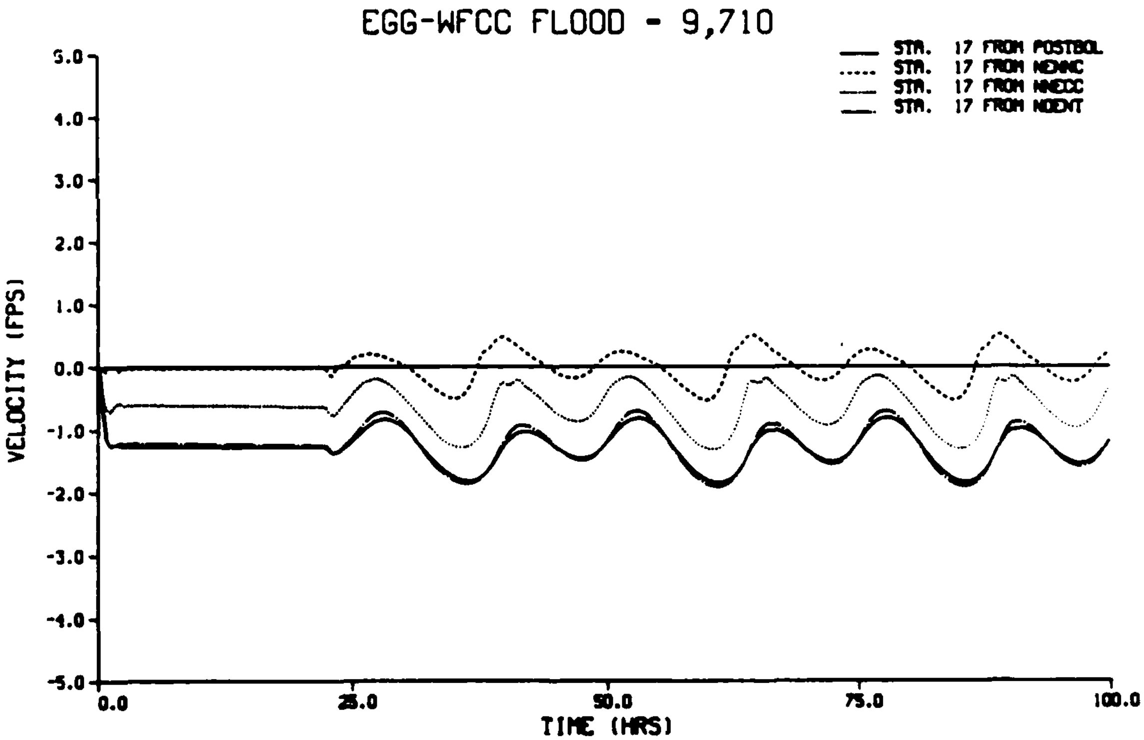


Figure 197. Average channel velocities in Huntington Harbour, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

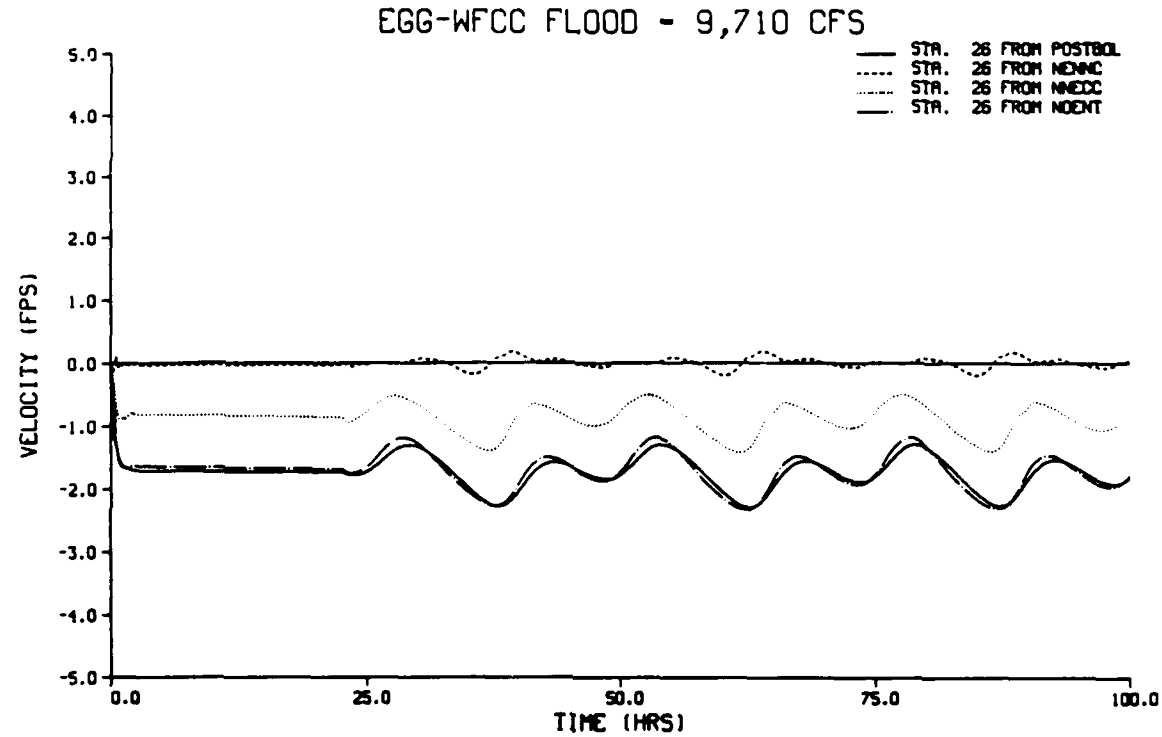


Figure 198. Average channel velocities in Huntington Harbour, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

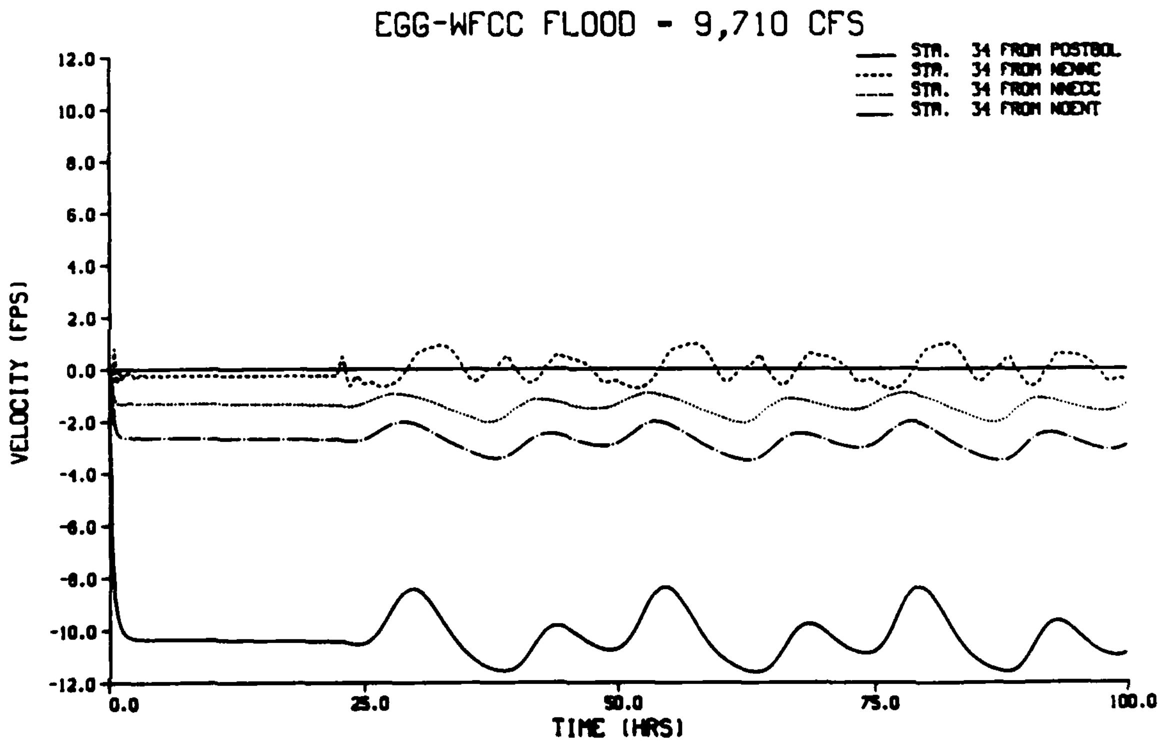


Figure 199. Average channel velocities at Warner Avenue bridge, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

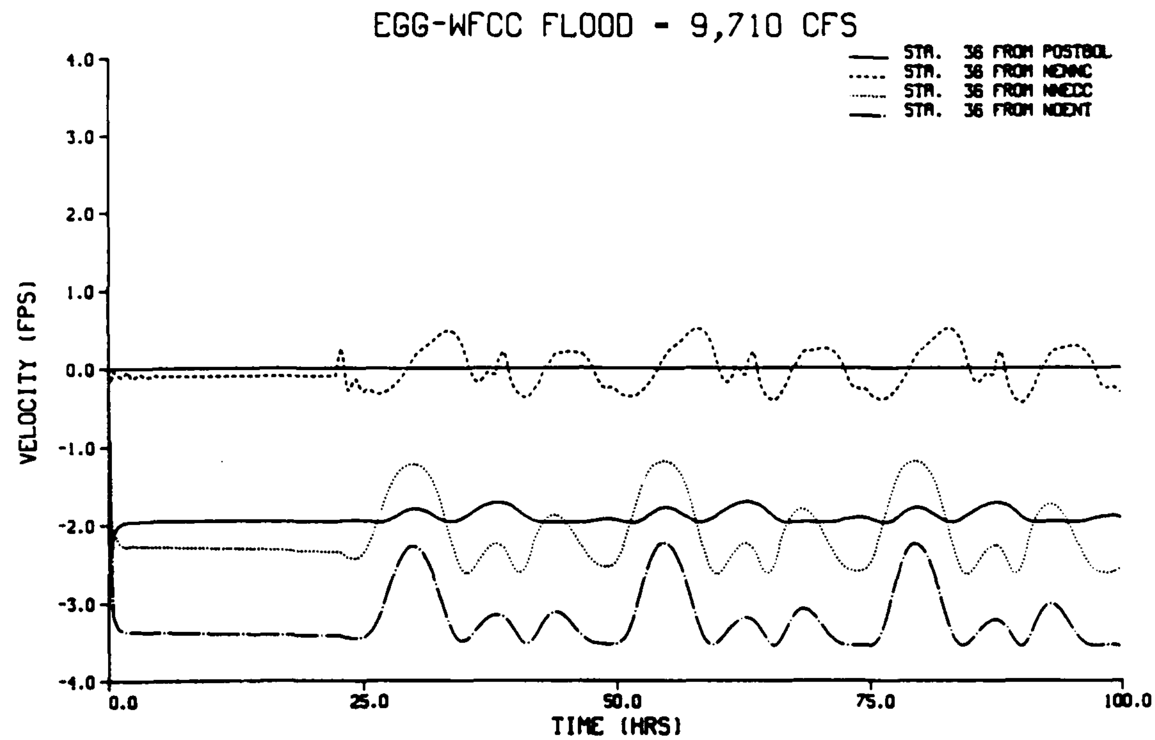


Figure 200. Average channel velocities in Outer Bolsa Bay, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

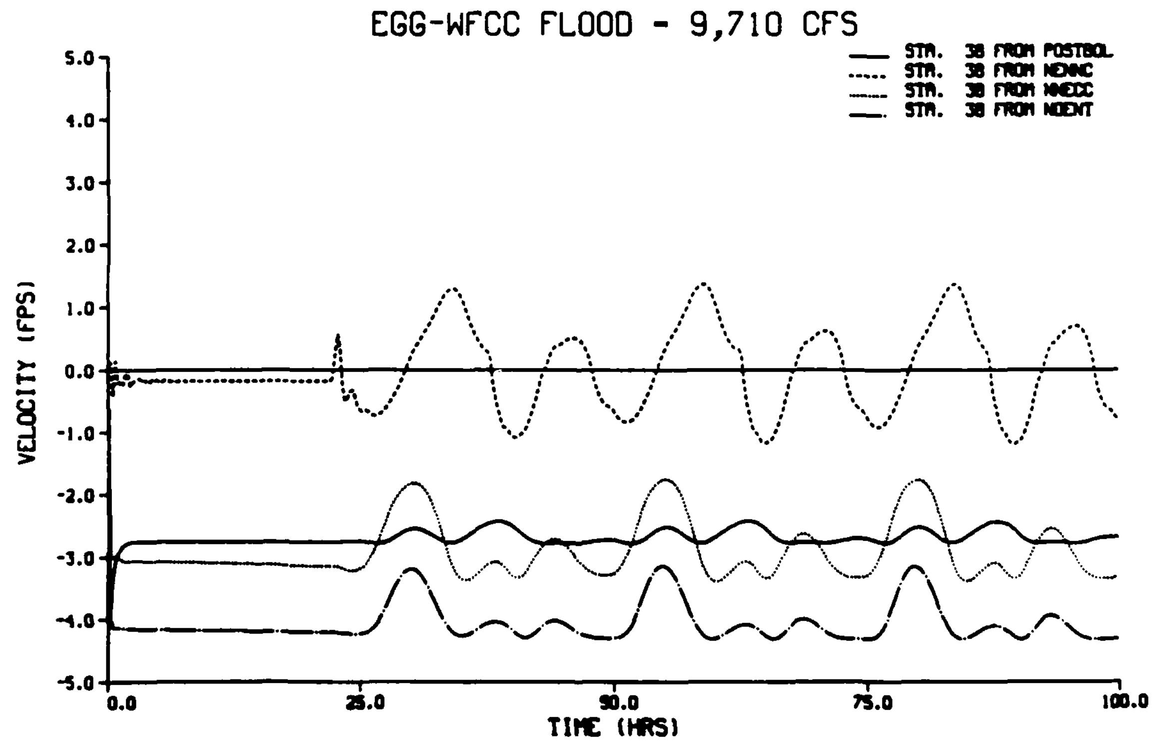


Figure 201. Average channel velocities in Outer Bolsa Bay, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

Table 18

Maximum Average Channel Velocities

Spring Tide plus 100-Year Flood Flow (9,710 cfs) in
East Garden Grove-Wintersburg Flood Control Channel

		Velocity, ft per sec				
Location	Link No	POSTBOL Spring	POSTBOL Flood	NENNC Flood	NNECC Flood	NOENT Flood
Pacific Coast Highway bridge	2	2.78	5.04	2.44	3.96	5.22
Huntington Harbour	5	1.42	3.18	1.21	2.37	3.29
Huntington Harbour	7	1.48	3.50	1.23	2.58	3.62
Huntington Harbour	10	0.71	1.88	0.59	1.36	1.95
Huntington Harbour	17	0.66	1.85	0.54	1.31	1.90
Huntington Harbour	24	0.57	2.11	0.42	1.41	2.18
Huntington Harbour	25	0.30	1.58	0.19	0.97	1.62
Huntington Harbour	26	0.34	2.30	0.20	1.42	2.33
Warner Avenue bridge	34	1.65	11.60	0.99	2.07	3.51
Outer Bolsa Bay	35	1.35	2.34	0.49	5.69	6.91
Outer Bolsa Bay	36	0.71	1.97	0.51	2.64	3.56
Outer Bolsa Bay	37	0.88	2.07	0.67	2.50	3.38
Outer Bolsa Bay	38	1.12	2.77	1.37	3.38	4.31
Proposed marina channel	39	----	----	2.12	----	----
Entrance channel	90	----	----	----	3.94	----
EGG-WFCC	93	----	----	----	4.03	3.25
Entrance channel	109	----	----	1.10	----	----

POSTBOL - existing conditions
NENNC - navigable entrance channel, with existing connection to Huntington Harbour
NNECC - non-navigable entrance channel, with existing connection to Huntington Harbour
NOENT - non-navigable entrance channel closed, with existing connection to Huntington Harbour

Non-navigable entrance, existing connector to Huntington Harbour

200. Maximum average channel velocities at Pacific Coast Highway bridge increase from about 2.8 ft per sec to about 4.0 ft per sec (40 percent increase), while velocities in Huntington Harbour increase up to about 2.6 ft per sec from about 1.5 ft per sec (70 percent increase). Because of the limited size of the non-navigable entrance channel, flow velocities through Outer Bolsa Bay increase up to about 5.7 ft per sec at Link 35 (a restricted link near Warner Avenue bridge) from about 1.4 ft per sec (300 percent increase). Other links of Outer Bolsa Bay experience lesser increases.

Non-navigable entrance closed, existing connector to Huntington Harbour

201. If the non-navigable entrance channel is permitted to close, maximum average channel velocities throughout the Bolsa Bay system will increase beyond those values estimated when the entrance is maintained open. In both cases, scouring velocity magnitudes will exist in Outer Bolsa Bay, and resulting shoaling will occur in the eastern portion of Huntington Harbour. Maximum average channel velocities will approach 5.2 ft per sec at the Pacific Coast Highway bridge, 3.6 ft per sec at Link 7 in Huntington Harbour, and 6.9 ft per sec at Link 35 in Outer Bolsa Bay. However, the entrance channel could be reopened immediately following a storm to alleviate excessively high velocities throughout Bolsa Bay. Even if the 100-year flood occurred and the proposed entrance channel at Bolsa Chica were not reopened immediately, scour expected to result from high velocities could be prevented by various channel stabilization measures provided as part of project construction.

PART XI: WATER QUALITY ASSESSMENT, HUNTINGTON HARBOUR AND BOLSA BAY

202. The available water quality data for the Huntington Harbour and Bolsa Bay complex were assembled and analyzed, and a limited field data collection effort was conducted during August 1987 to supplement the existing data base. Water quality data for the system were summarized for existing conditions, for both conventional and toxic water quality constituents.

Data Sources

Orange County Environmental Management Agency

203. The Orange County Environmental Management Agency (OCEMA) monitors seven stations within the Huntington Harbour complex (Figure 202). Dissolved oxygen, pH, temperature, and conductivity are measured monthly at these stations. Semi-annual or quarterly sampling of turbidity, nitrates plus nitrites, and phosphates are measured at HUNHAR, HUNSUN, HUNBCC, HUNCRB, HUNWAR, and BBOLR stations. Semi-annual sampling of the water column and sediments are conducted for analysis of trace metals, pesticides, herbicides, and polychlorinated biphenyls at the two stations downstream of flood control channels (HUNBCC and BBOLR). In addition, extensive monitoring of Bolsa Chica, Westminister, and East Garden Grove-Wintersburg Flood Control Channel is performed both periodically and during storm events. These data are compiled in the Environmental Protection Agency (EPA) STORET system and are available for public access. OCEMA is the primary source of water quality data for the area (Orange County Environmental Management Agency 1986).

California Regional Water Quality Control Board

204. Data collected in the Huntington Harbour and Bolsa Bay area by the California Regional Water Quality Control Board (CRWQCB) typically are in the realm of special studies (Olsen 1988). There is an ongoing Mussel Watch program which includes stations in Huntington Harbour (Stephenson et al. 1986). Caged mussels are set out at specific locations in the harbor and serve as biointegrators for contaminants in the area. Mussels are harvested yearly and analyzed for trace metals and organic contaminants. In addition, CRWQCB performed a contaminant survey in the Huntington Harbour area during

1987. Sediment and water column samples were collected in April and August 1987, and analyzed for both trace metals and organic contaminants.

<u>Orange County Health Care Agency</u>

205. The Orange County Health Care Agency (OCHCA) performs bacteriological sampling in the Huntington Harbour area and in Outer Bolsa Bay. Sampling is done at 12 stations in the area on a weekly basis to determine coliform levels. Coliform levels are an indicator of human and animal wastes.

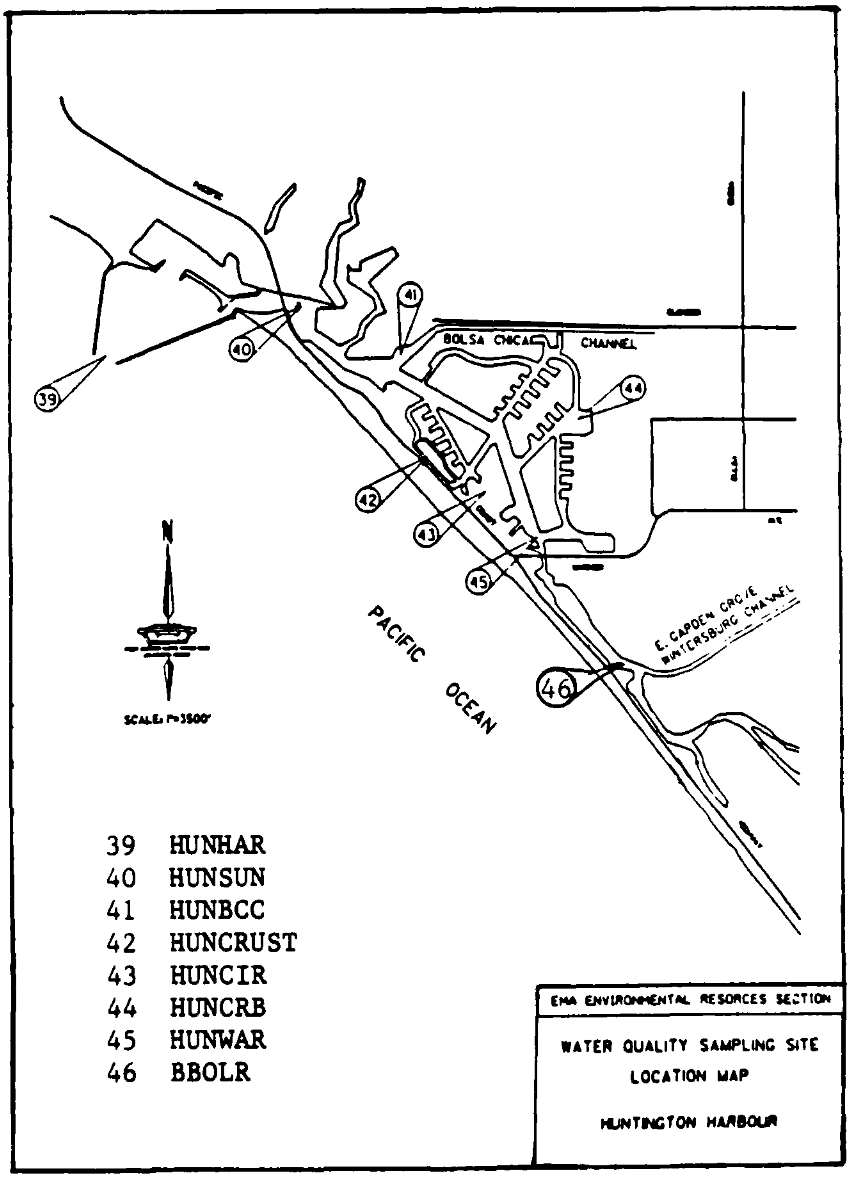


Figure 202. Orange County Environmental Management Agency (OCEMA) sampling stations in Huntington Harbour

Dillingham survey and Feldmuth survey

206. The Dillingham survey (Stein et al. 1971) provides a background environmental evaluation of the Bolsa Chica area prior to the opening of the tide gates between Outer Bolsa Bay and Inner Bolsa Bay in 1978. The Feldmuth et al. (1980) survey conducted during 1979-1980 covered the period when the second tide gate into the muted tidal area (Inner Bolsa Bay) was opened. The DFG muted tidal area was not constructed during this study.

Coastal Dynamics

207. A limited water quality survey was performed during August 1987 while Coastal Dynamics (Meadows 1987) was conducting a wave and tide data collection effort to supplement the existing data base, and these data were used in the course of this evaluation. Dissolved oxygen, temperature, pH, and salinity were measured in the water column at three locations, and sediment samples were taken at three locations (Figure 203). Average values of the water quality parameters from the water column are shown in Table 19. Sediment sample parameters for trace metals are given in Table 20, and pesticides and PCBs are shown in Table 21. In Huntington Harbour, dissolved oxygen, and temperature were measured at surface, mid-depth, and bottom. Conductivity and pH were measured only at mid-depth. For the Bolsa Bay stations where water depths are relatively shallow, measurements were taken at mid-depth for all stations. Sediment analysis gives a better time-averaged picture of toxins in a system rather than simply reflecting the current runoff conditions. Additionally, many contaminants may not be detectable at water column concentrations even though substantial accumulation may occur in the

Table 19

Average Values of Water Quality Parameters

Huntington Harbour, Outer Bolsa Bay, and Inner Bolsa Bay

	Dissolved Oxygen mg/liter	pH	Conductivity ohms/cm	Temperature deg C
Huntington Harbour	5.0, 4.9	8.0, 8.1	65.4, 69	20.5, 21
Outer Bolsa Bay	4.8	8.1	68.6	23.2
Inner Bolsa Bay	3.9	8.2	69.0	23.5

Source: Meadows (1987)

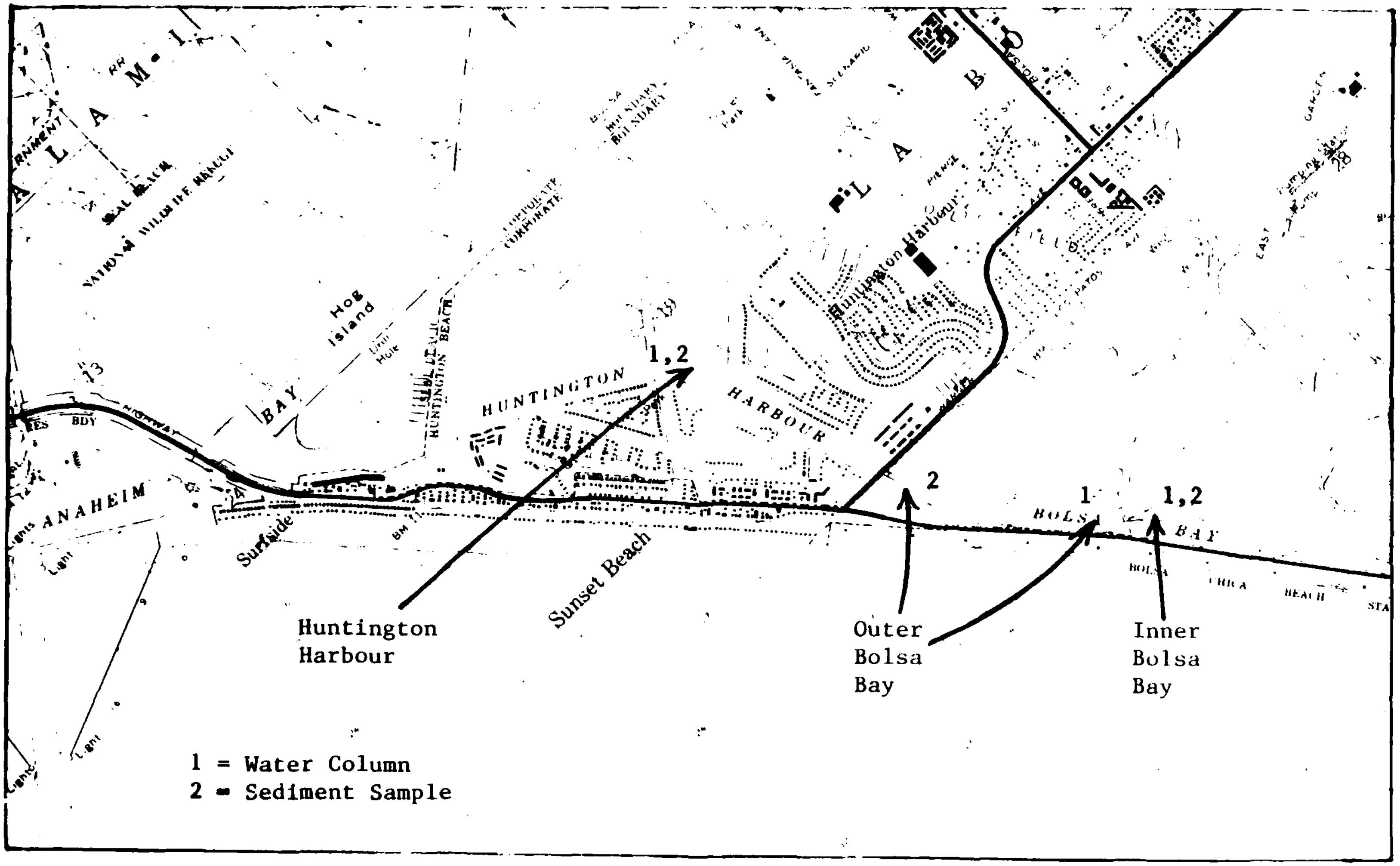


Figure 203. Location of water column (dissolved oxygen, pH, salinity, temperature) and sediment (trace metals) sampling stations by Meadows (1987)

Table 20

Sediment Analyses for Trace Metals

Huntington Harbour, Outer Bolsa Bay, and Inner Bolsa Bay

	Huntington Harbour mg/kg	Outer Bolsa Bay mg/kg	Inner Bolsa Bay mg/kg
Arsenic	3.8	3.6	4.8
Cadmium	0.44	0.28	0.51
Chromium	19.2	13.8	51.2
Copper	30.8	22.2	29.9
Lead	15.5	21.6	21.1
Mercury	nd	nd	nd
Nickel	13.2	9.6	21.1
Silver	0.2	0.1	0.2
Zinc	93.8	73.1	102.0

Source: Meadows (1987)

sediment. Toxic materials which persist in the sediment and are not rapidly flushed from the system are, in general, the compounds which present the greatest environmental threat.

Guidelines for Evaluation of Water Quality Parameters

208. California DFG issued a set of recommendations to SLC in a memorandum of 15 May 1987 for water quality parameters which should be considered in the Bolsa Chica ocean entrance studies (Radovich 1987). For the constituents where these guidelines are specified, the assessment of current conditions was made with reference to these values. Additionally, comparisons were made to the conditions observed at the entrance to Huntington Harbour, Station HUNHAR. The water at this station is relatively "clean" (as good as is possible for the system), and represents a standard to which the other stations can be compared.

209. No sediment quality criteria for toxins has yet been established, although work to establish such criteria is underway by EPA. Development of sediment criteria is a controversial area since there may not be a direct correlation between sediment concentrations and the potential environmental impact of disturbing that sediment. A sediment classification criteria used

Table 21

Sediment Analyses for Pesticides and PCBs

Huntington Harbour, Outer Bolsa Bay, and Inner Bolsa Bay

	Huntington Harbour mg/kg	Outer Bolsa Bay mg/kg	Inner Bolsa Bay mg/kg
Aldrin	-	-	-
Alpha-BHC	-	-	-
Beta-BHC	-	-	-
Gamma-BHC	-	-	-
Delta-BHC	-	-	-
Chlordane	-	-	-
4,4'-DDD	-	-	-
4,4'-DDE	0.024	0.018	0.028
4,4'-DDT	0.0075	0.0091	0.0094
Dieldrin	-	0.0004	0.0002
A-Endosulfan	-	-	0.0002
B-Endosulfan	-	-	-
Endrin	-	-	-
Endrin Aldehyde	-	-	-
Heptachlor	-	-	0.0003
Heptachlor Epoxide	-	-	-
PCB-1016	-	-	-
PCB-1221	-	-	-
PCB-1232	-	-	-
PCB-1242	-	-	-
PCB-1248	-	-	-
PCB-1254	-	-	-
PCB-1260	-	-	-
Toxaphene	-	-	-

Source: Meadows (1987)

for a while by EPA Region V in determining acceptable disposal methods for dredged materials is given as a reference for trace metal concentrations. These values are highly controversial and should not be considered as strict guidelines, and used only as a frame of reference. Mussel Watch data were compared to US Food and Drug Administration (FDA) action levels for contaminants in food where these were available. Alternately, it was compared to the Australian National Health and Medical Research Council (ANHMRC) Standards for Metals in Foods. FDA has not yet set action levels for metals in foods.

Assessment of Existing Water Quality Conditions

Water temperature

210. DFG recommends a maximum temperature of 90 deg F for June-October and 78 deg F for the remainder of the year. Maximum temperatures in the area are observed in August. At the OCEMA HUNWAR and BBLOR stations for the period 1980 - 1986, August highs are typically in the 79 - 81 deg F range. For the August 1987 study sponsored by WES (Meadows 1987), average temperatures in the tidally muted area of Bolsa Bay were on the average 0.4 deg F higher than in Outer Bolsa Bay (Table 19). Feldmeth et al. (1980), in an extensive water quality survey of Bolsa Bay, found temperatures in Inner Bolsa Bay to be slightly higher than Outer Bolsa Bay, but values throughout the area were well within DFG guidelines. Temperature is not presently a stressful parameter for the area.

pH

211. DFG recommends pH remain within a range of 7.0 - 8.6. Typically, values reported throughout Huntington Harbour are within this range. Only one exceedance value was reported at the BBLOR station in the OCEMA data. Both the Feldmeth et al. (1980) and the Meadows (1987) survey (Table 19) showed values within this range for both Outer Bolsa Bay and Inner Bolsa Bay.

Dissolved oxygen

212. DFG recommends that dissolved oxygen (DO) never fall below 5.0 mg per liter. Figures 204 through 209 show the DO levels at the OCEMA stations as compared to the ocean boundary (HUNHAR) station. HUNHAR can be considered the clean water, or undegraded condition. The bars in these figures show the DO measurements over the depth. Typically, the high DO values were recorded near the surface and the low DO values at the bottom. The HUNHAR values were taken near the water surface. The dotted line represents 5.0 mg per liter, and any readings below this line are below the DFG critical level. All of the stations show substantial degradation below the level of the ocean boundary station. HUNCRB, located in Christiana Bay at mid-channel, shows frequent incidence of low DO at the channel bottom. There is a large variation in DO over the depth at this station, indicating that poor mixing exists back in this area.

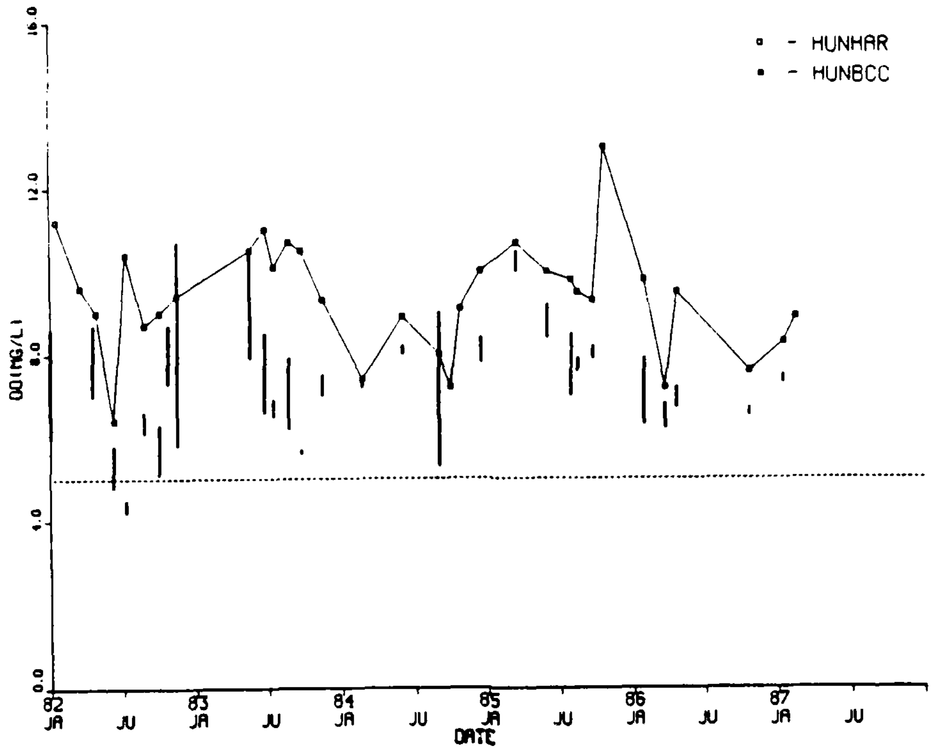


Figure 204. Dissolved oxygen observed at OCEMA Station HUNBCC compared with Station HUNHAR

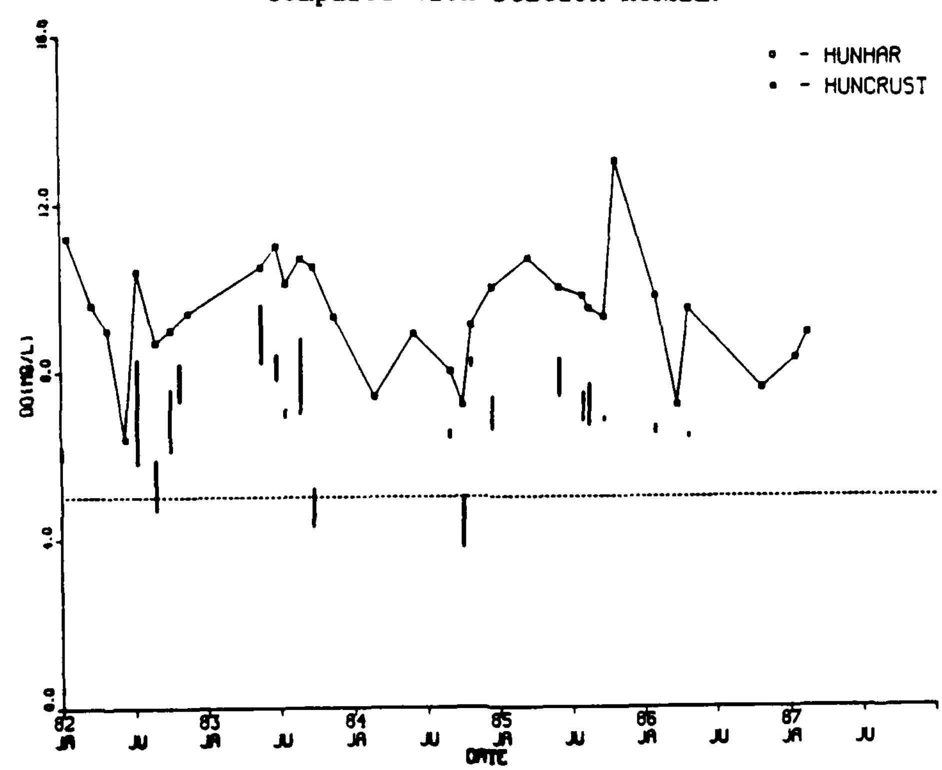


Figure 205. Dissolved oxygen observed at OCEMA Station HUNCRUST compared with Station HUNHAR

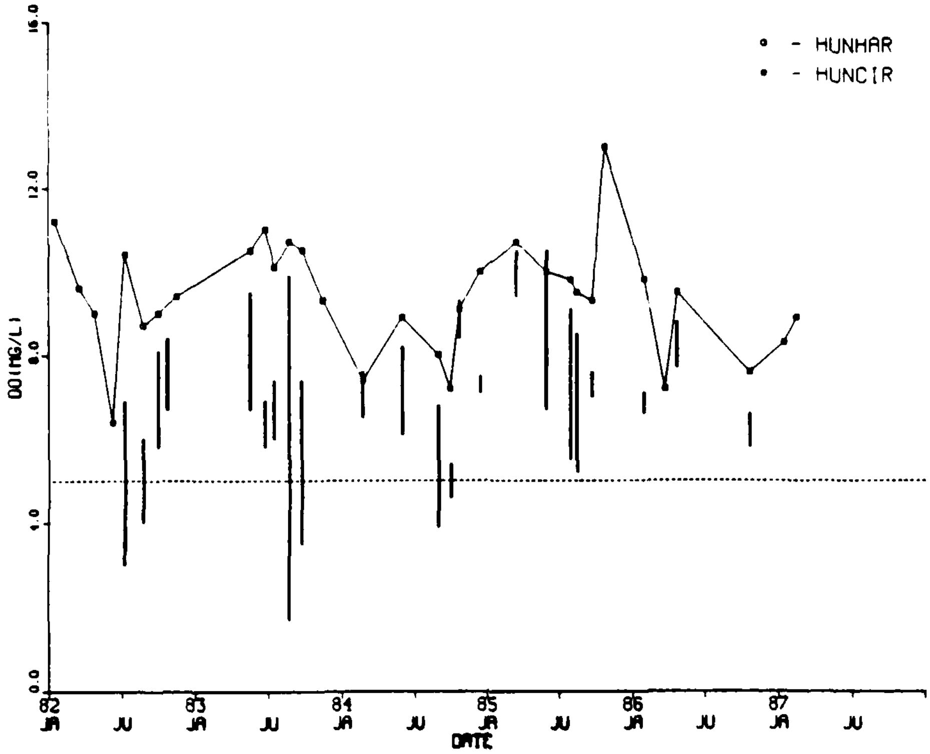


Figure 206. Dissolved oxygen observed at OCEMA Station HUNCIR compared with Station HUNHAR

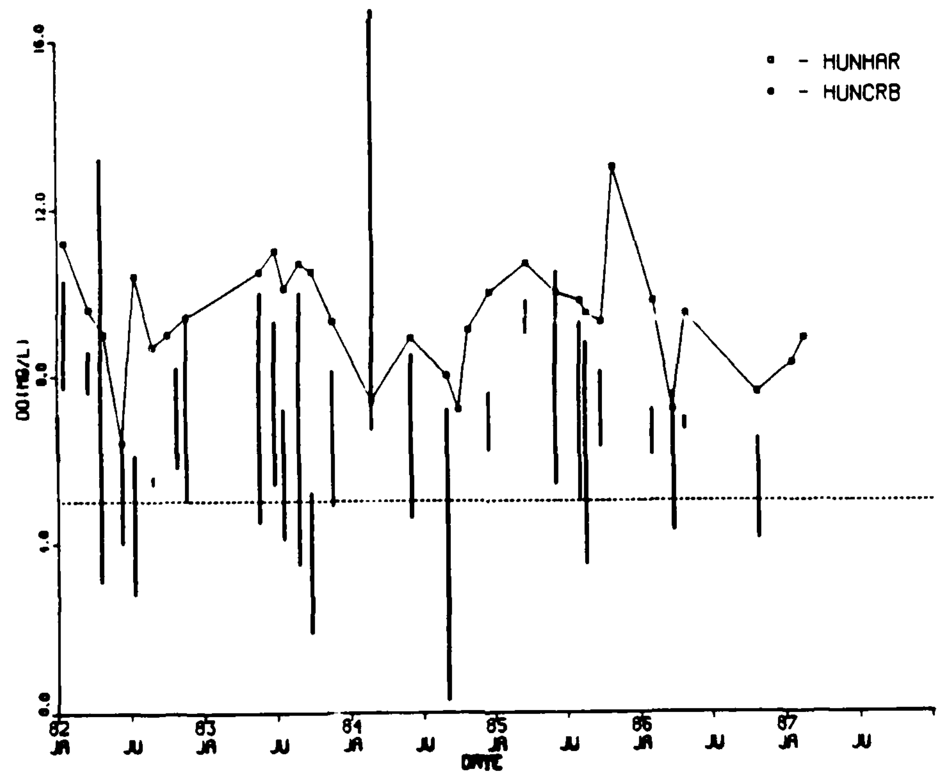


Figure 207. Dissolved oxygen observed at OCEMA Station HUNCRB compared with Station HUNHAR

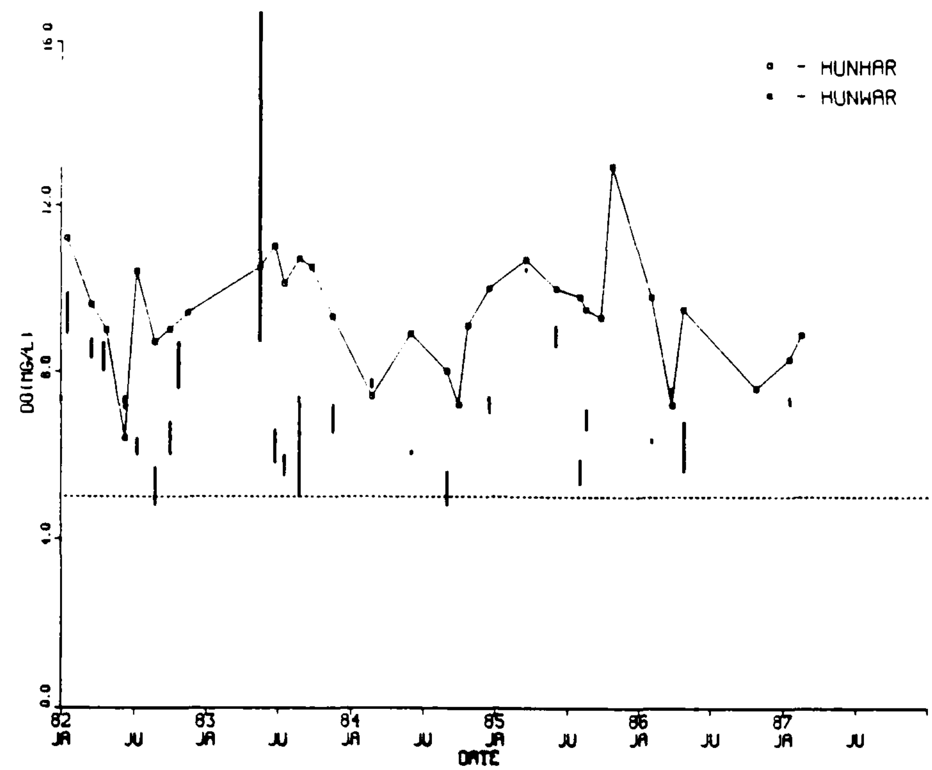


Figure 208. Dissolved oxygen observed at OCEMA Station HUNWAR compared with Station HUNHAR

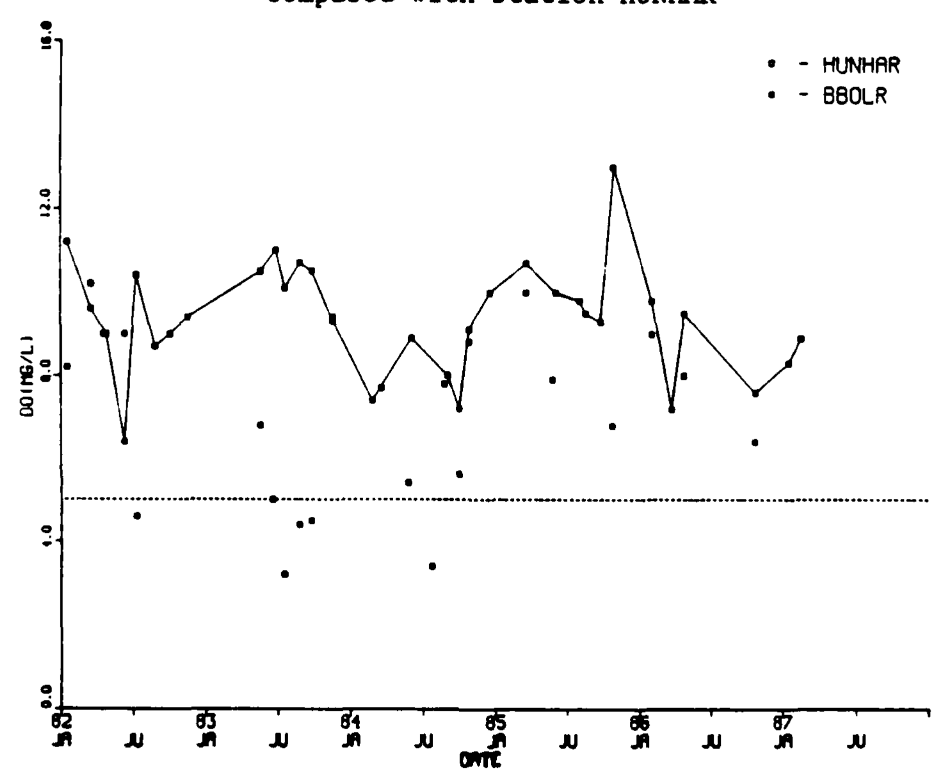


Figure 209. Dissolved oxygen observed at OCEMA Station BBOLR compared with Station HUNHAR

213. Only one vertical reading was taken at the station in the Outer Bolsa Bay area since this is a relatively shallow area. There are several DO readings below the critical level during the summer. No measurements of DO were taken in this area during June - August after 1984, which is probably why there were no readings below the critical levels in 1985 - 1986. In the Meadows (1987) survey during August 1987, the average DO for the sample period in Outer Bolsa Bay and Inner Bolsa Bay (Table 19) were both below 5.0 mg per liter. Low DO observed in previous years is probably a continuing problem.

214. DO criteria are violated in the deeper waters of Huntington Harbour and Bolsa Bay during the summer. No instances of anoxia (total depletion of oxygen in the water column), which results in a noxious malodorous condition and fish kills, were reported. Maintenance of a minimum DO of 5.0 mg per liter, however, is considered necessary for maintenance of a varied fish population. Fish embryonic and larval forms are particularly sensitive to low DO since they are not generally as efficient in extracting oxygen from the water, and they cannot move away from adverse conditions. Inability to maintain the desired DO levels is a major limitation for the area's capacity as a fish nursery.

Nutrients (phosphates and nitrates)

215. Concentrations of phosphate and nitrate in the Bolsa Chica system are not elevated over values at the Huntington Harbour entrance. In a productive area such as the Inner Bolsa Bay region, nutrient depletion, rather than nutrient excess, is more apt to be the problem. During the Feldmeth et al. (1980) study of the Bolsa Bay region, phosphate depletion was observed in the South Bolsa Slough portion of Inner Bolsa Bay when only one port of the tide gate was open. During this period, several other conditions indicative of stagnation were observed in this area, including elevated ammonia levels and tea-brown water color with low clarity. Subsequent to the opening of the second port of the tide gate, ammonia levels dropped, water clarity improved, and phosphate levels were uniform throughout Inner Bolsa Bay and Outer Bolsa Bay. As long as sufficient tidal flushing is maintained throughout the area, nutrient levels are maintained. However, primary productivity in the wetlands may be nutrient-limited without sufficient tidal exchange.

Bacteriological contamination

216. Elevated coliform levels in a water body are an indicator of contamination by human or animal wastes. OCHCA monitors coliform contamination at 12 stations in the Huntington Harbour complex five times per month. The water contact sports standards specifies no more than 20 percent of samples at a sample station per month (or one for the Huntington Harbour sampling schedule) may exceed 1,000 Most Probable Number (MPN) coliforms per 100 ml. Several stations within a given quarterly period may be in violation of this standard. Elevated coliform levels in Huntington Harbour are often related to run-off events. Elevated coliforms due to storm events do not present a public health hazard, other than potentially masking genuine contamination. Occasional violations occur which may be associated with vessel wastes, urban surface drainage, or other human activity in the sampling area. Contamination was usually temporary with subsequent sampling yielding reduced coliform levels.

Trace metals

217. Metals typically of concern include copper, zinc, lead, cadmium, chromium, arsenic, selenium, mercury and iron. The DFG established the following guidelines for metal concentration in the water column:

Cadmium	0.010 ppm
Chromium	0.050 ppm
Mercury	0.002 ppm
Copper	0.020 ppm
Zinc	0.100 ppm
Arsenic	0.050 ppm

At the HUNWAR station, OCEMA data for the period from 1983 - 1985 showed no exceedance of these criteria. At the BBOLR station, these guidelines were exceeded once for zinc (0.12 ppm) and copper (0.04 ppm) out of nine observations. Station BBOLR is near the runoff outfall for the East Garden Grove-Wintersburg Flood Control Channel. Observations in the channel itself showed a more frequent incidence of exceedance values for copper and zinc.

218. While dissolved concentrations of contaminants reflect discharge/runoff events concurrent with the sampling, the trace metal concentrations in the sediment and mussels reflect a more time integrated view of contaminant loadings in the system. Felumeth et al. (1980) observed lead levels in Inner Bolsa Bay sediments to be equivalent to lead concentrations in Outer Bolsa Bay

sediments. Prior to opening the tide gates, lead concentrations in Inner Bolsa Bay sediments were appreciably lower than in Outer Bolsa Bay. They concluded that, although opening the tide gates had increased tidal flushing and reduced stagnation, it had also allowed toxic materials from East Garden Grove-Wintersburg Flood Control Channel to be diverted into Inner Bolsa Bay. There was a high degree of variability of lead concentrations within the sites sampled in Outer Bolsa Bay and Inner Bolsa Bay areas.

219. Trace metal concentrations for sediment samples taken during the Meadows (1987) field survey are shown in Table 22. Most of the metal concentrations in Huntington Harbour, Outer Bolsa Bay, and Inner Bolsa Bay are of the same order. Sediment concentrations of trace metals in Outer Bolsa Bay taken near the outfall of the East Garden Grove-Wintersburg Flood Control Channel from three separate studies performed in 1987 (Meadows 1987; Stang 1987; Earth Technology Corporation 1987) are presented in Table 22. Overall, lead levels are somewhat lower than those observed in the Feldmeth et al. (1980) survey (an average of 55 mg/kg). Zinc concentrations are somewhat higher than in the Feldmeth et al. (1980) survey. However, due to the

Table 22

Sediment Analyses for

Trace Metal Concentrations in Outer Bolsa Bay

(mg/kg dry weight)

	WES (1)	CRWQCB (2)	Earth Technology (3)	Highly Polluted (4)
Arsenic	3.6	2.9	1.2	8.0
Cadmium	0.28	1.00	0.39	6.00
Chromium	13.8	11.0	8.9	75.0
Copper	22.2	16.0	11.0	50.0
Lead	21.6	34.0	40.0	60.0
Mercury	nd	nd	nd	nd
Nickel	9.6	6.0	5.5	50.0
Silver	0.1	0.2	0.2	-
Zinc	73.0	81.0	66.0	200.0

Source: (1) Meadows (1987)
(2) California Regional Water Quality Control Board (1987)
(3) Earth Technology Corporation (1987)
(4) EPA Region V Sediment Classification Criteria

variability of the data and possible differences in sampling and analysis, this comparison is not conclusive. Some decline in lead concentrations might be expected due to increased use of unleaded gasoline.

220. The conclusions of the CRWQCB from the 1987 contaminant survey in the Huntington Harbour area, based on their sediment sampling of the runoff channels, is that zinc, arsenic, and lead are the trace metals of concern for that area. However, there are no good criteria available for sediment quality. Mussel Watch data provide a biological indicator of contaminants which are a problem in the area. Relatively high concentrations of a contaminant may be present in the sediment but if it is not in a form which is bioavailable, then it is not likely to have a significant environmental impact. Mussel Watch data collected at Warner Avenue bridge during the period 1985 - 1986 for selected metals are presented in Table 23, and compared to ANHMRC guidelines for metals in foods. (FDA action levels have not been established.) Lead, zinc, and cadmium are above the levels recommended for human consumption. Mussel Watch data were not available for arsenic, the other trace metal which CRWQCB designated as a potential problem.

Table 23

Trace Metal Concentrations in Mussels of Outer Bolsa Bay at Warner Avenue Bridge

	Mussel Watch 85-86 (1) mg/kg, dry weight	Wet Weight Equivalent mg/kg	ANHMRC (2) Maximum Allowed Concentration Mollusks mg/kg, wet weight
Cadmium	11.5	2.3	1.0
Copper	13.0	2.6	70.0
Lead	32.0	6.4	2.5
Mercury	0.5	0.1	0.5
Zinc	386.0	-	1.0

Source: (1) Stephenson (1986), California Regional Water Quality Control Board Mussel Watch Program
(2) Australian National Health and Medical Research Council, Standards for Metals in Foods

Organic contaminants

221. No toxic organic compounds are typically detected in the water column based on the CRWQCB 1987 survey of the area and OCEMA data. Sediment samples show trace amounts of certain organochlorine pesticides. The CRWQCB detected aldrin, lindane, DDD, DDE, and DDT at all of their sampling sites. The WES survey (Meadows 1987) data of Table 21 detected DDE, and DDT in the sediment samples, where no trace organics were detected in sediment analysis performed by Earth Technology Corporation (1987). PCBs and PAHs do not appear to be present in detectable quantities. Results from the Mussel Watch sampling indicated concentrations for the organic toxicants evaluated in this program were within FDA action levels. Chlordane levels, however, were the highest in the state along the Newport Beach area.

222. Tributyltin (TBT), used as the active biocide in most marine antifouling paints, is a contaminant of concern in coastal harbors and marinas with a high density of pleasure craft. A limited sampling of tributyltin was carried out during 1986 in Huntington Harbour by the California State Water Quality Control Board (SWQCB), and a more extensive sampling was performed by the CRWQCB in 1987. The 1986 sampling identified "hot spot" harbors. The 1987 survey presents a more balanced view of TBT levels in Huntington Harbour. During the 1987 sampling program, all samples were under 100 parts per trillion. Levels observed in channels were typically an order of magnitude lower than observed in marina/boatyard areas less than one-half mile away. TBT occurrence in Huntington Harbour appears to be localized. The TBT problem in Huntington Harbour does not appear to be as serious as in other areas of the state. However, some locations in Huntington Harbour are TBT input sources.

Water Quality Assessment Summary

223. Three categories of water quality problems presently existing or potentially arising need to be considered in evaluating impacts of proposed alternatives to develop and enhance wetlands of Bolsa Bay.

224. First, dissolved oxygen concentrations are violated occasionally in Bolsa Bay, and in the deeper waters of Huntington Harbour during the summer months. An additional ocean entrance will provide a source of water with

higher dissolved oxygen concentrations. However, additional development will potentially increase biological oxygen demand (BOD) sources to the area (increased vessel wastes and runoff).

225. Second, certain trace metals and organic toxicants are detected in sediments throughout the area. Trace metals appearing at elevated levels in the sediments include lead, zinc, arsenic, and cadmium. Accumulation of these metals in fish and wildlife presents a potential human health hazard as well as threatening a thriving wildlife population. Chlordane and organochlorine pesticide residues are detected throughout Huntington Harbour and Bolsa Bay. TBT is observed in localized portions of Huntington Harbour, but appears to be relatively immobile. Use of TBT has recently been prohibited and, therefore, the impacts and concentrations occurring in the system should decline in the future. Increased flushing with an additional ocean entrance will tend to mediate problems associated with system toxicants.

226. Third, low flushing in the muted tidal wetlands has resulted in stagnation conditions in the most interior portions of the wetlands. Primary productivity within the wetlands may be nutrient-limited without sufficient tidal exchange. Under present conditions (only one entrance to the wetlands), improving tidal exchange appears to have resulted in an increase in toxicant levels in the muted tidal wetland areas.

PART XII: EVALUATION OF TRANSPORT CHARACTERISTICS

227. DYNTRAN simulations were performed to evaluate the impacts of proposed entrance plans on the transport and mixing characteristics in the Huntington Harbour and Bolsa Bay complex. First, overall residence time or water age was calculated for the whole system. Ocean water is in a comparatively clean condition, and residence time in the system generally corresponds to degradation of the water quality. Although there is not a direct correspondence, and other factors certainly may improve or degrade water quality conditions, the residence time does serve as an indicator of system water quality, particularly in the harbor and marina areas. Rapid flushing within the wetland itself is not an a priori beneficial condition. Next, transport of runoff from East Garden Grove-Wintersburg Flood Control Channel (EGG-WFCC) was simulated for the major plan configurations. EGG-WFCC is the major source of toxic materials into the muted tidal wetlands.

228. This series of simulations only addressed the potential impacts of circulation changes in the system on water quality. No attempt was made to estimate the potential increase in development and recreational use in the area associated with alternate proposed plan conditions, or the potential impact on pollutant loadings associated with those recreational use increases.

Tidal Boundary Driver

229. The tidal boundary conditions used for the transport tests are shown in Figure 210. This signal is simply the tidal pattern from constituents at the NOAA Los Angeles-Long Beach tide gage for the month of September 1988. For the water age calculation, 1,375 hr of simulation were performed. The September tidal pattern was repeated for the additional simulation time. In the runoff tests, the first 200 hr were utilized. The September 1988 tides do not contain the extreme high and low tide range observed in this area, and utilized in the hydrodynamic simulations. However, this lower tidal range condition is a more environmentally stressful condition; i.e., system flushing is lower for lower tidal ranges.

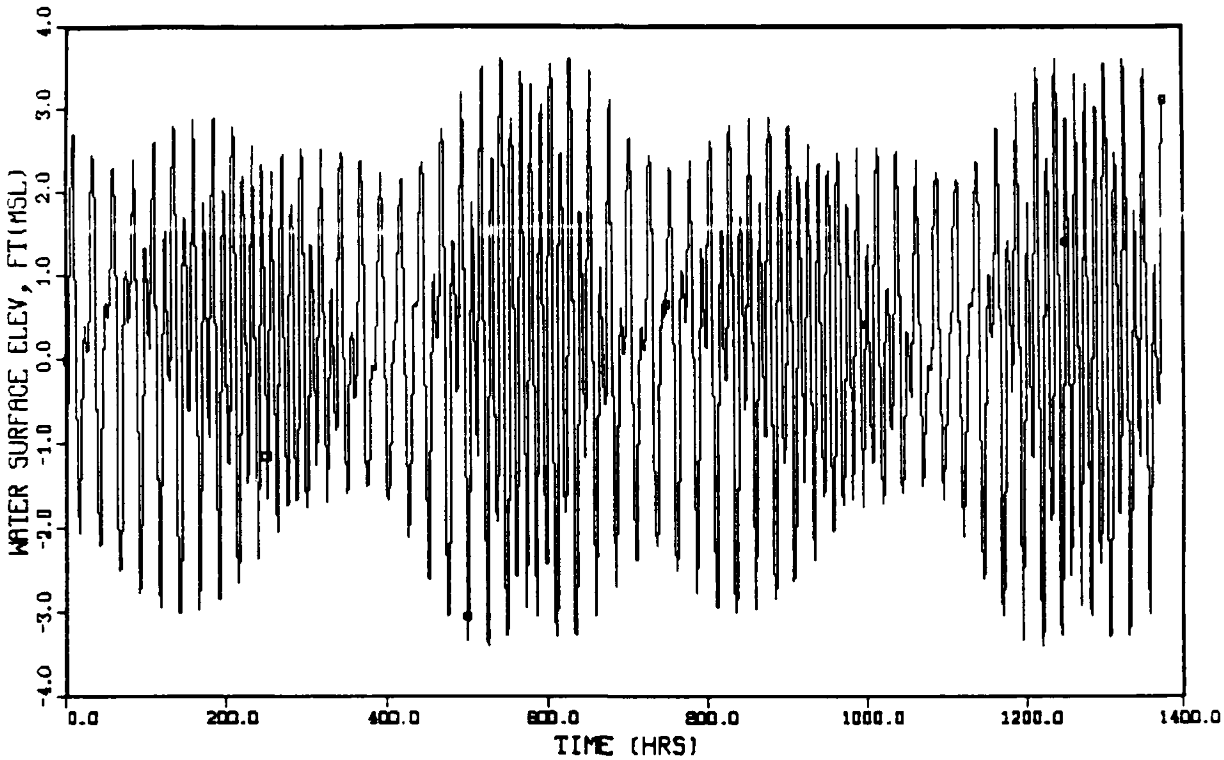


Figure 210. Tidal boundary driver (September 1988) for transport and mixing characteristics, Bolsa Bay, and vicinity

System Water Age

230. In this series of tests, the average age for a parcel of water (i.e., the time since that parcel of water left the ocean) was calculated for the existing condition (POSTBOL), and for each of the 12 proposed plan variation conditions previously described. These 12 variations include:

a. NENC1: Navigable entrance channel, navigable connector channel to Huntington Harbour, wetlands connected,

b. NENC2: Navigable entrance channel, navigable connector channel to Huntington Harbour, wetlands not connected,

c. NENNC1: Navigable entrance channel, non-navigable connector channel to Huntington Harbour, wetlands connected,

d. NENNC2: Navigable entrance channel, non-navigable connector channel to Huntington Harbour, wetlands not connected,

e. NNECC3: Non-navigable entrance channel, non-navigable connector channel to marina, wetlands connected,

f. NNECC1: Non-navigable entrance channel, non-navigable connector channel to marina, wetlands not connected,

g. NNECC4: Non-navigable entrance channel, no connector channel to marina, wetlands connected,

h. NNECC2: Non-navigable entrance channel, no connector channel to marina, wetlands not connected,

i. NOENT4: Non-navigable entrance channel closed, non-navigable connector channel to marina, wetlands connected,

j. NOENT1: Non-navigable entrance channel closed, non-navigable connector channel to marina, wetlands not connected,

k. NOENT3: Non-navigable entrance channel closed, no connector channel to marina, wetlands connected, and

l. NOENT2: Non-navigable entrance channel closed, no connector channel to marina, wetlands not connected.

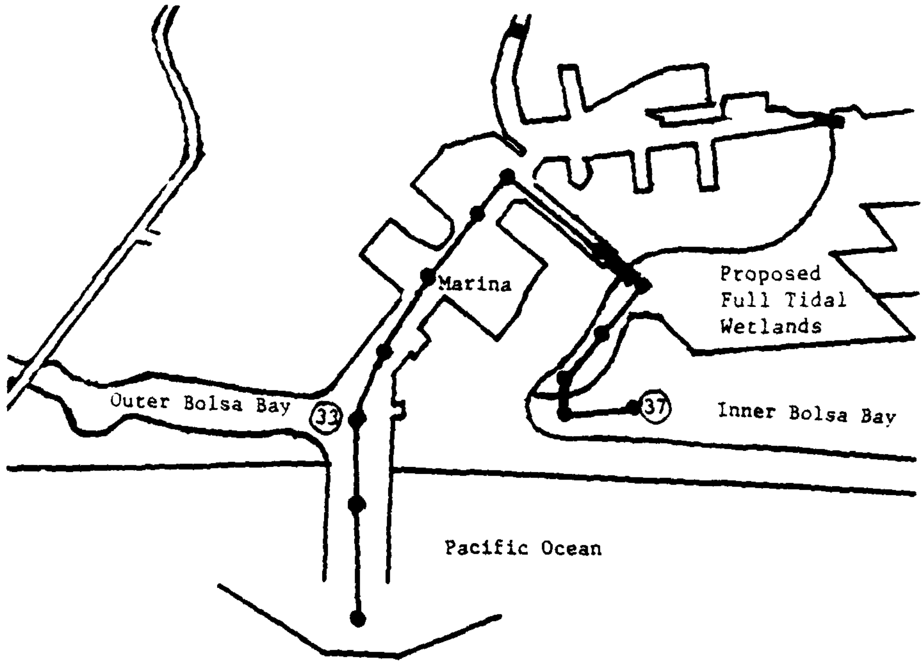
An additional simulation for the navigable entrance was performed with a non-navigable channel connecting Node 33 in the marina to Node 37 in Inner Bolsa Bay through a 4-ft-diam culvert system (2 pipes in, 3 pipes out, Figure 211).

231. Water age was calculated by setting the age of the ocean water equal to zero, and solving the following "water age" transport equation:

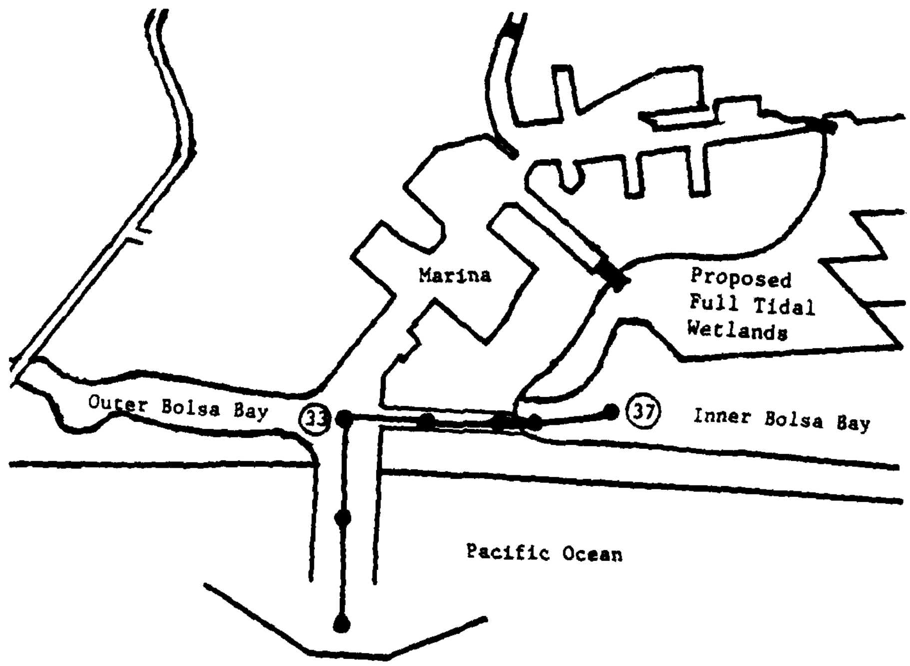
$$\frac{\partial}{\partial t} (V_i \ Ag_i) = \sum_{k=1}^{K} (Q_k \ Ag_k) + Q_I \ Ag_i + \sum_{k=1}^{K} (Ag_k \ E_L \ \frac{\partial Ag_k}{\partial x}) + V_i \tag{15}$$

Here Ag_i is the age of the water in node i, and the other variables have previously been defined in PART III. The form of the source/sink term is the only alteration for the age calculation to the transport equation given in PART III. The solution technique for the transport equation is the same as previously described in that previous PART III.

232. Use of the decay time boundary option was overridden in the model in this case, and a 0.0 boundary value was specified as follows. For the existing entrance, the age boundary (i.e., the location where the water was considered outside the system) was taken at the boundary of Node 1. Water age was set to zero in Nodes 73 and 74 at the Anaheim Bay entrance (Figure 19). Similarly, for the planned entrance alternatives, the zero boundary was set at the edge of the land rather than at the boundary of the nodes extending out into the ocean. For the navigable entrance alternative, water age was set to zero in Nodes 76 and 77 (Figure 43). For the non-navigable entrance, water



a. Original flow path between Node 33 and Node 37



b. Supplemental channel between Node 33 and Node 37

Figure 211. Paths for flow between Pacific Ocean and Inner Bolsa Bay

age was maintained at zero in Nodes 78 and 79 (Figure 83). For all the water age simulations, the hydrodynamic model was started at a zero velocity condition and zero water surface elevation (msl), and allowed 25 hr (two complete tidal cycles) for model spinup before starting the water age calculations. Water age was initially zero throughout the entire system.

233. For existing conditions, water age results are presented graphically for Nodes 9, 15, 17, 24, 32, 35, 40, and 54 in Figures 212 through 219, respectively (location of nodes shown on Figure 19). The graphs demonstrate several general characteristics of the aging simulations. During the initial phase of the simulations, the water age increases linearly. As the system equilibrates, the water age oscillates with the tidal variations in a plateau range. At Node 9 (Figure 212) in the main channel of Huntington Harbour, velocities are relatively high, and water moves rapidly in from the ocean and back out, resulting in large variations in water age over a tidal cycle at this location. In the side channels of Huntington Harbour (Figures 213 and 214) where flow is low, intertidal variations are decreased and average water age is much higher. These side channel areas occasionally have low DO,

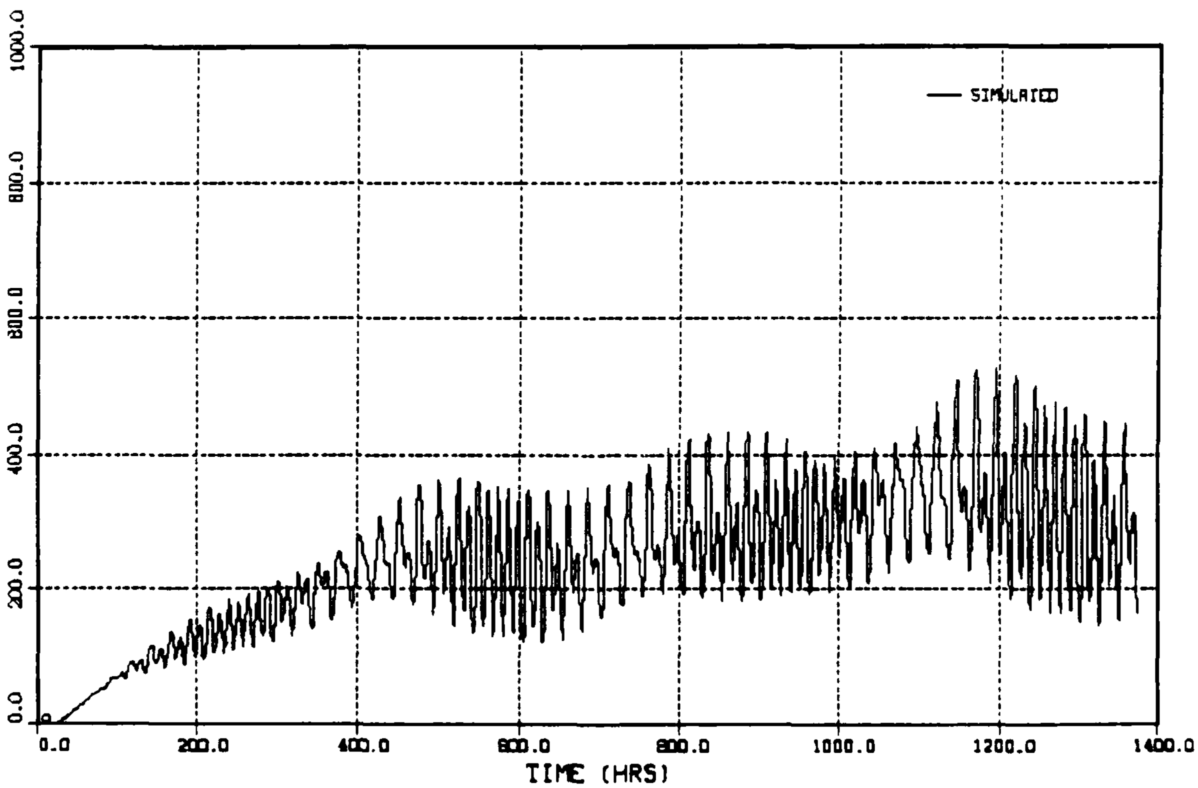


Figure 212. Water age for Node 9 existing conditions, main channel, Huntington Harbour

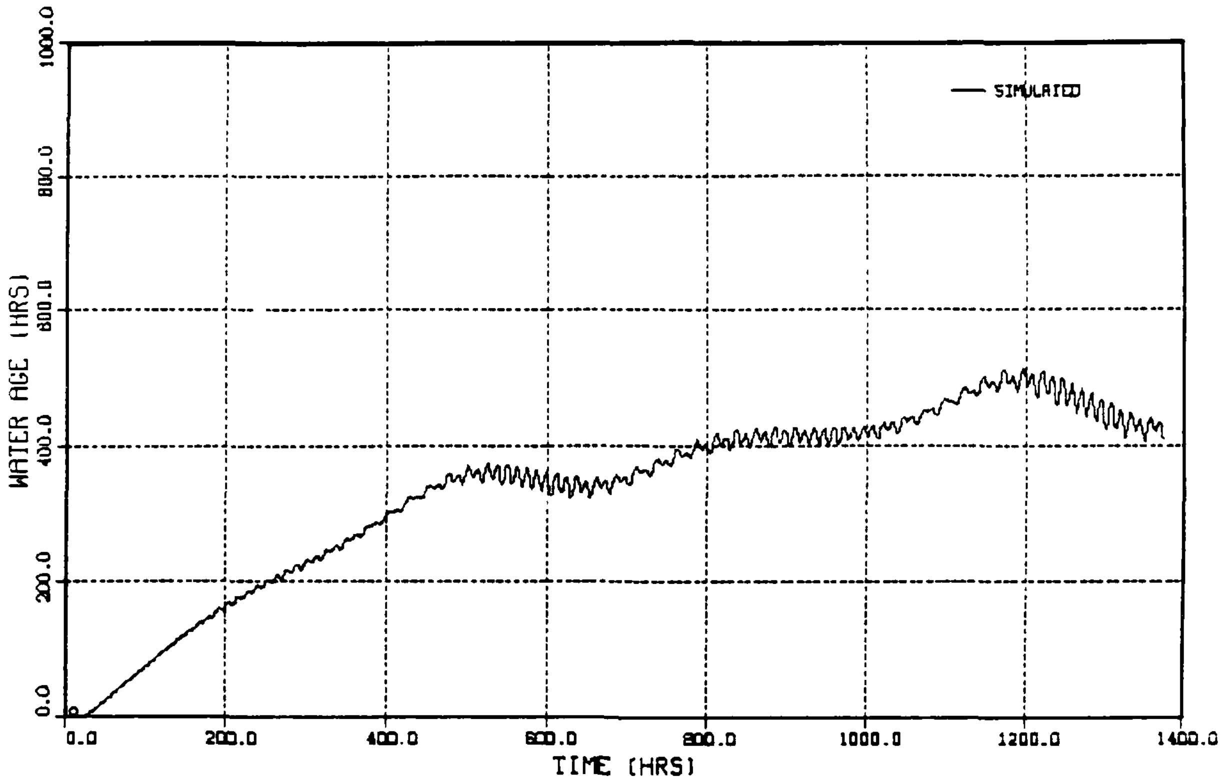


Figure 213. Water age for Node 15 existing conditions, side channel, Huntington Harbour

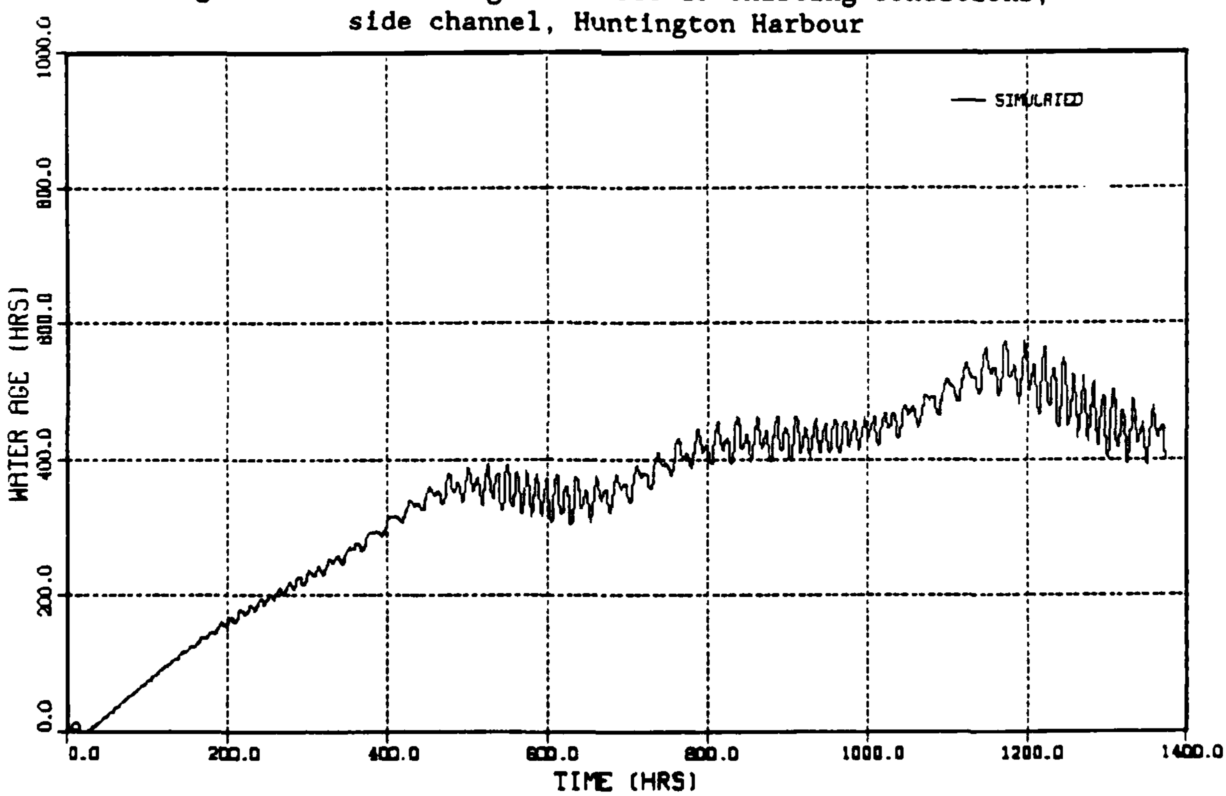


Figure 214. Water age for Node 17 existing conditions, side channel, Huntington Harbour

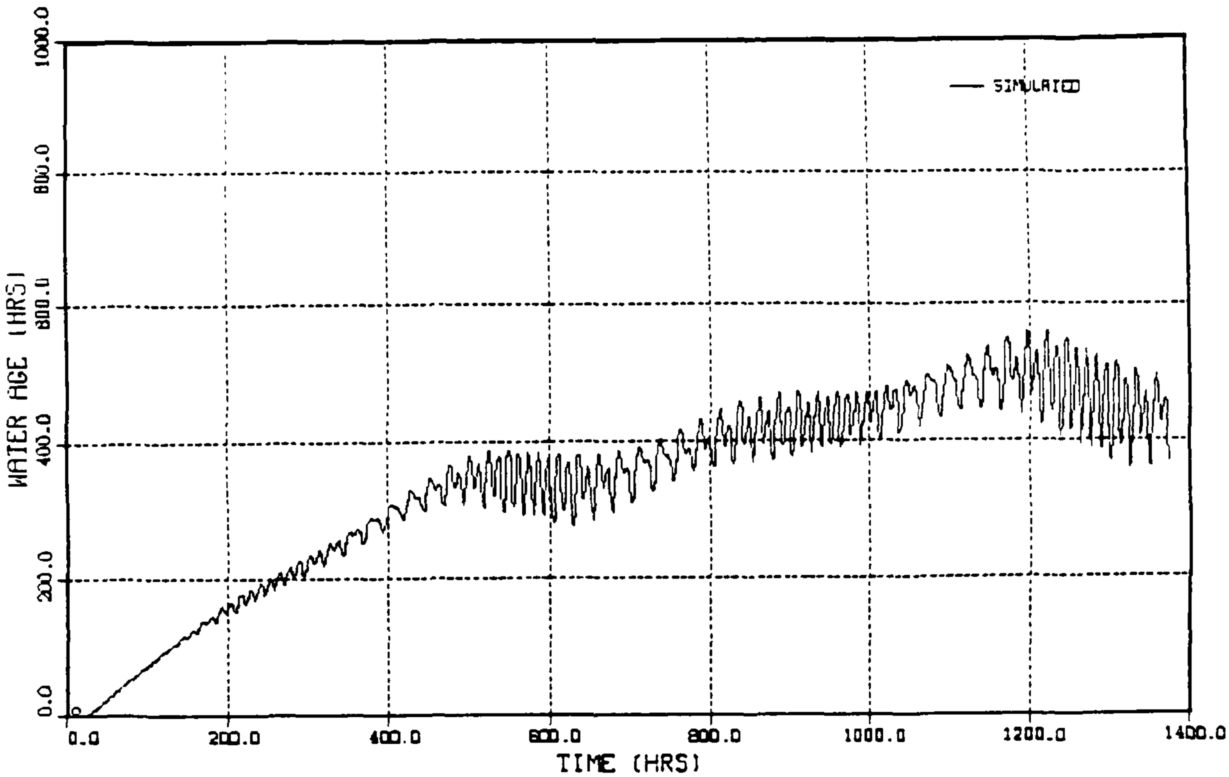


Figure 215. Water age for Node 24 existing conditions, main channel, Huntington Harbour

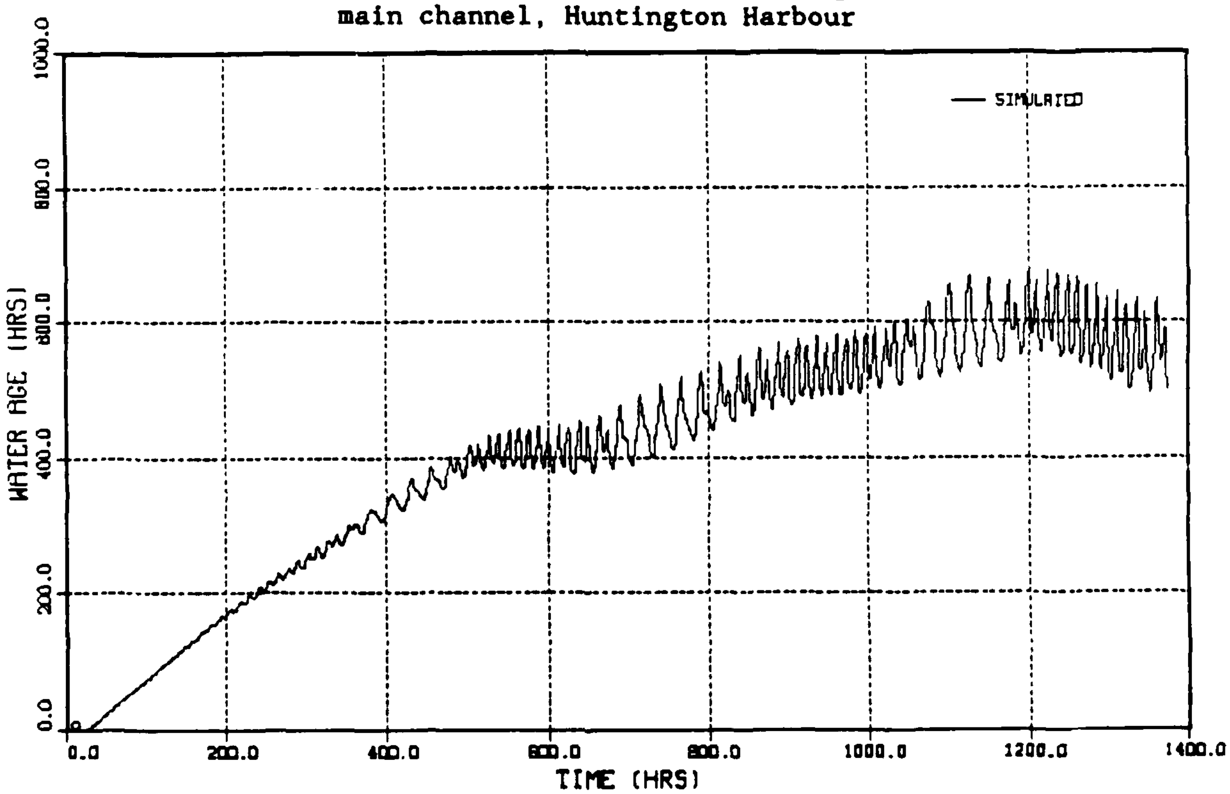


Figure 216. Water age for Node 32 existing conditions, Outer Bolsa Bay

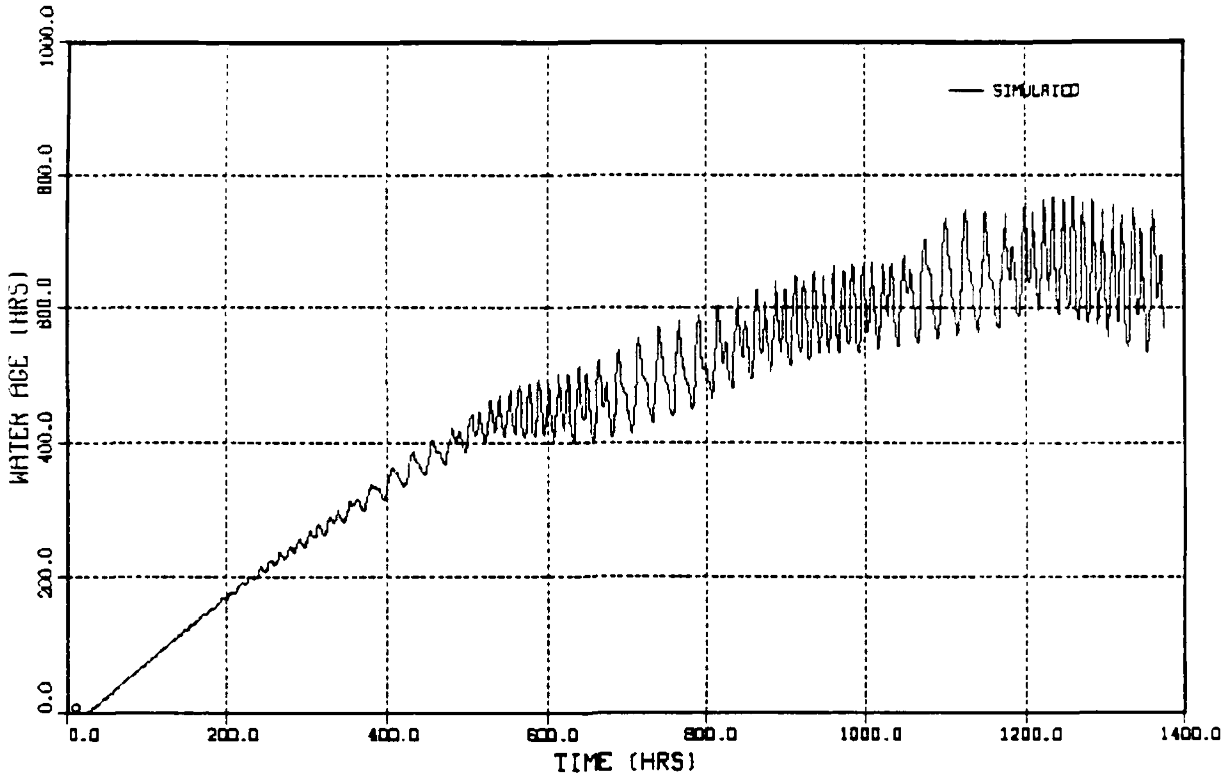


Figure 217. Water age for Node 35 existing conditions, Inner Bolsa Bay

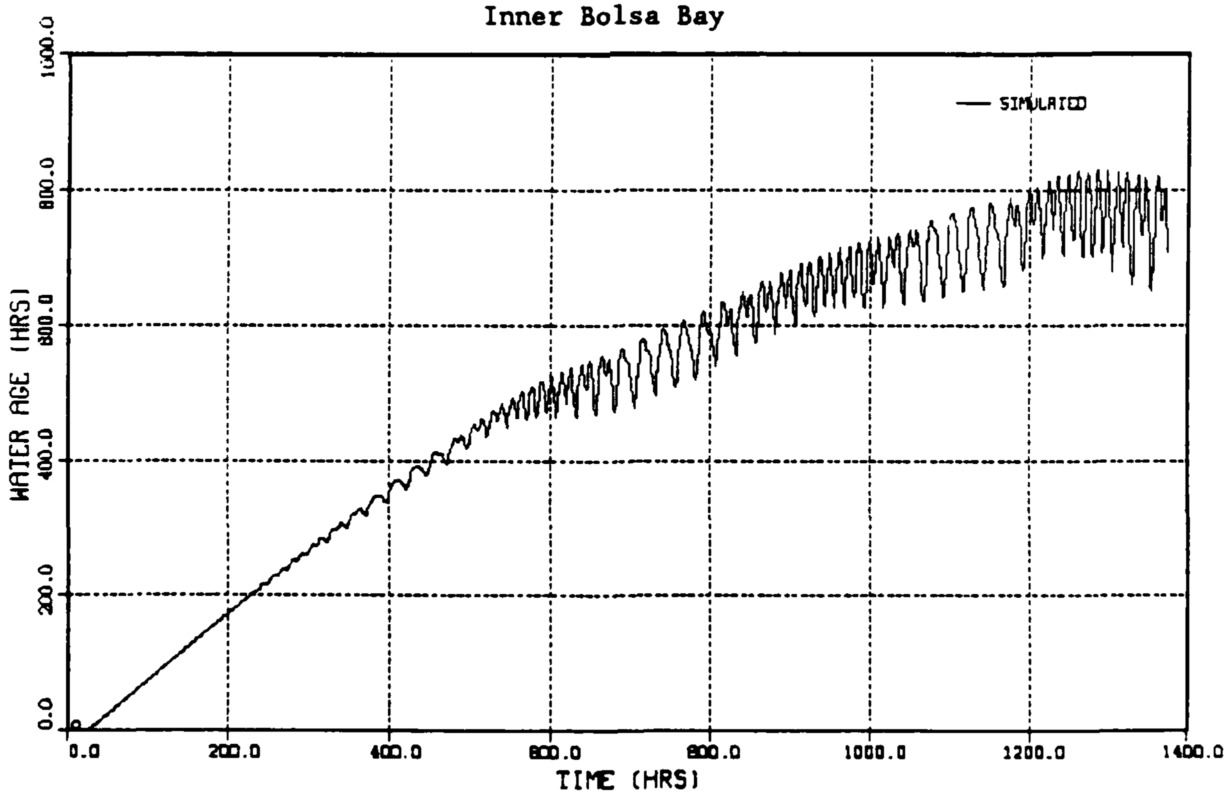


Figure 218. Water age for Node 40 existing conditions, Inner Bolsa Bay

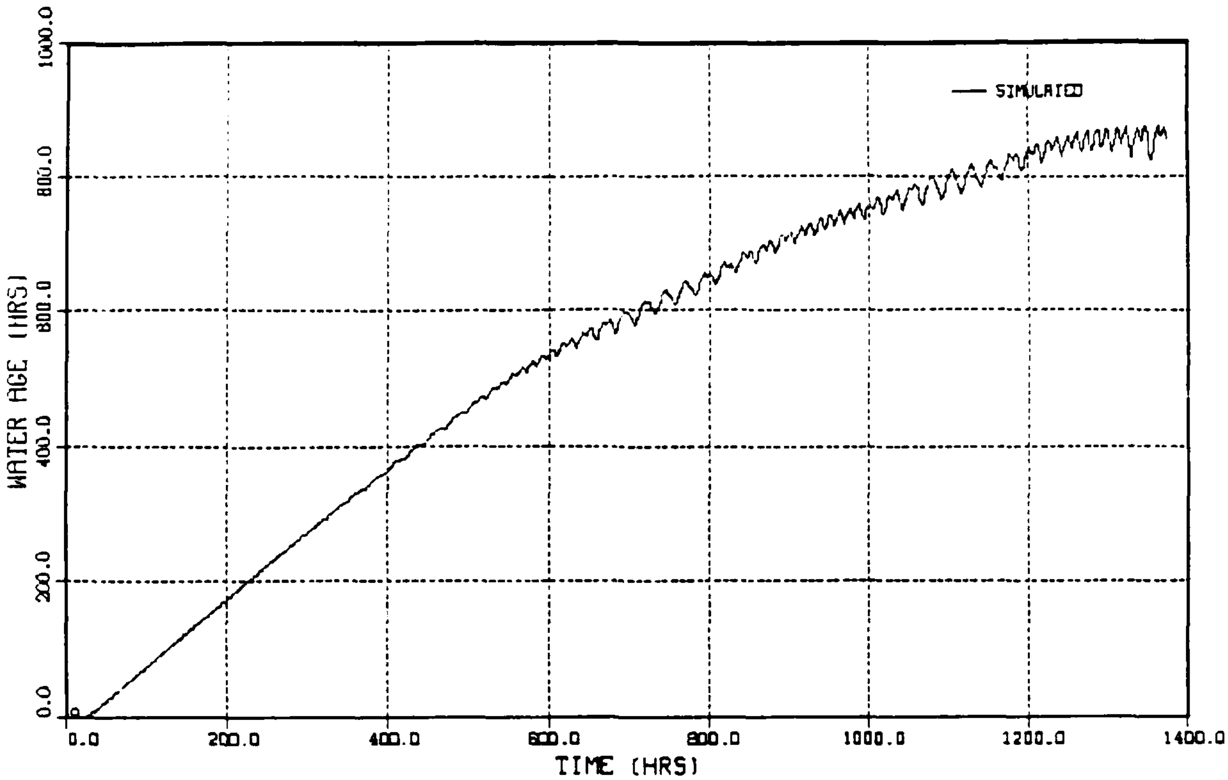


Figure 219. Water age for Node 54 existing conditions, DFG muted tidal cell

particularly in the deeper reaches due to increased residence time, low vertical mixing, and biological oxygen demand (BOD) sources in the marinas. As the water moves away from the Anaheim entrance into Bolsa Bay, average age increases. In the DFG muted tidal cell, water age equilibrates to over 800 hr (a residence time in the system of more than a month), and tidal oscillations are damped.

234. Table 24 summarizes the ageing results for a series of nodes in Huntington Harbour and Bolsa Bay under existing conditions, and for the proposed navigable entrance channel concept and its variations, including the additional simulation in which Node 33 in the proposed marina is connected to Node 37 in Inner Bolsa Bay by a supplemental non-navigable channel and culvert system. Table 25 summarizes the corresponding ageing results for the non-navigable entrance channel concept and its variations, including the closed entrance channel condition. The average age for the final 25 hr (two full tidal cycles) of simulation is shown in these tables. Several notable features may be observed from these estimates.

Table 24

Water Age

Huntington Harbour and Bolsa Bay, California

Existing Conditions versus Navigable Entrance Concepts

Average Age (hours) for Final 25 hours of Simulations

		Navigable Entrance Channel				
		Navigable Connector Channel to Huntington Harbour		Existing Outer Bolsa Bay Channel to Huntington Harbour		
Node #	Existing Condition	Wetlands Connected	Wetlands Not Connected	Wetlands Connected	Wetlands Not Connected	Supplemental Channel to Inner Bolsa Bay, Wetlands Connected
9	281	343	343	173	173	173
15	425	576	576	289	289	289
17	435	637	637	302	302	303
24	434	366	366	289	289	290
29	487	274	275	339	339	338
37	684	256	220	321	284	106
40	751	357	293	423	360	155
54	855	466	397	531	465	230
111	---	383	395	451	463	357
122	---	430	447	495	512	442
129	---	394	417	460	482	415
134	---	390	421	455	486	420

Table 25

Water Age

Huntington Harbour and Bolsa Bay, California

Existing Conditions versus Non-Navigable and No Entrance Concepts

Average Age (hours) for Final 25 hours of Simulation

		Non-Navigable Entrance Channel				No Entrance Channel			
		By-Pass Connector Channel To Marina		No By-Pass Connector Channel To Marina		By-Pass Connector Channel To Marina		No By-Pass Connector Channel To Marina	
Node #	Existing Condition	Wetlands Connected	Wetlands Not Connected	Wetlands Connected	Wetlands Not Connected	Wetlands Connected	Wetlands Not Connected	Wetlands Connected	Wetlands Not Connected
9	281	143	143	142	142	257	256	266	265
15	425	259	258	254	253	417	416	425	424
17	435	243	243	236	236	399	398	410	409
24	434	223	223	241	240	387	386	397	396
29	487	241	240	268	266	431	430	441	438
37	684	75	73	74	72	567	571	555	557
40	751	117	107	117	106	659	620	627	613
54	855	224	185	224	185	745	710	755	710
107	---	185	197	188	203	723	744	724	749
127	---	166	184	169	190	701	735	704	742
111	---	169	180	172	185	700	729	711	735

235. One feature of interest is the increase in residence time at the nodes through the mid-section of Huntington Harbour, for the navigable entrance channel with a navigable connector channel. As discussed previously in PART VI, there exists a low velocity zone where the flow through the two entrances meet near the middle of Huntington Harbour for the navigable entrance with a navigable connector channel concept. The average water age at Nodes 9, 15, and 17 increased 30 to 50 percent over existing conditions for this plan configuration. Two features of this low velocity zone are apparent in the time histories of these three nodes (Figures 220 through 222) when compared to existing conditions (Figures 212 through 214). First, there is the increase in the plateau levels for the simulations as reflected in the increase in the average age values shown in Table 24. In addition, there is a pronounced decrease in the amplitude of the tidal oscillations for the water age due to the decreased water movement through this section.

236. This alteration in circulation will adversely affect dissolved oxygen in the Huntington Harbour marina areas. The dissolved oxygen resources could be stressed by the increased retention time for the water in these

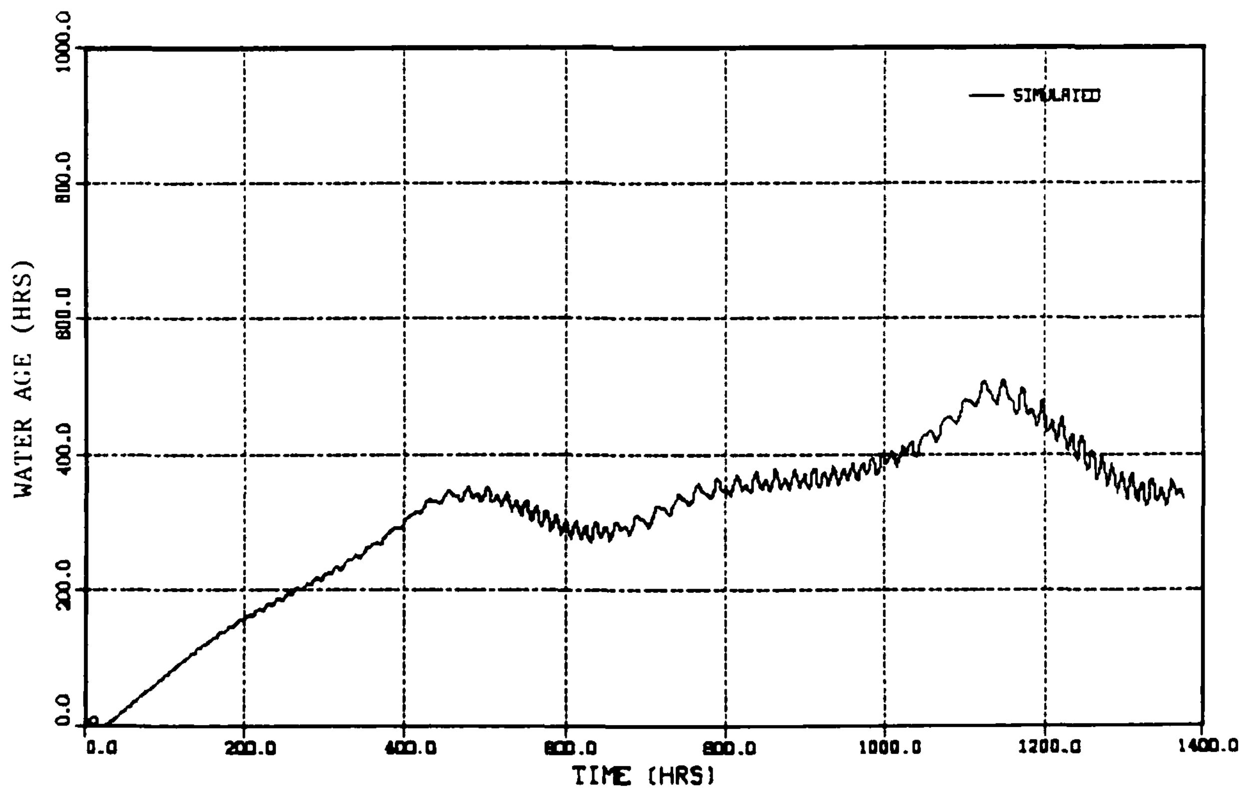


Figure 220. Water age for Node 9, main channel, Huntington Harbour, navigable entrance and navigable connector to Huntington Harbour

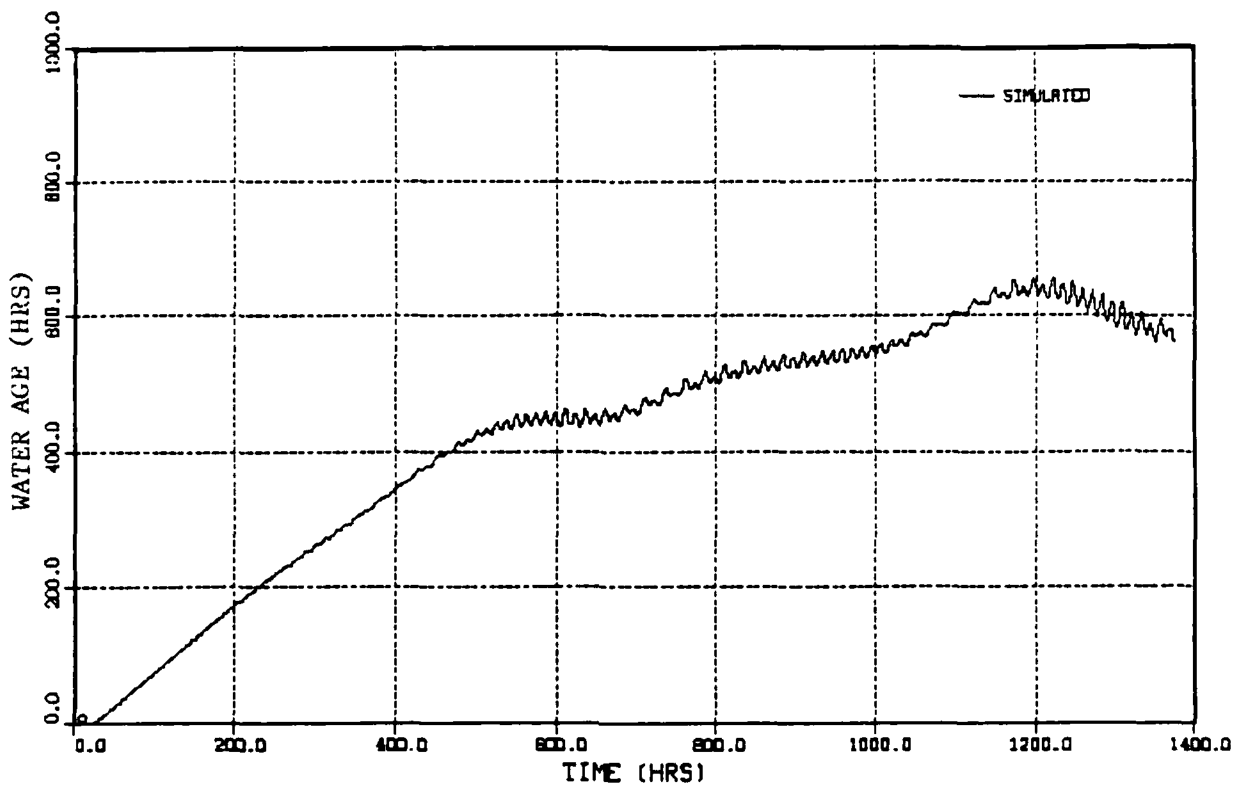


Figure 221. Water age for Node 15, side channel, Huntington Harbour, navigable entrance and navigable connector to Huntington Harbour

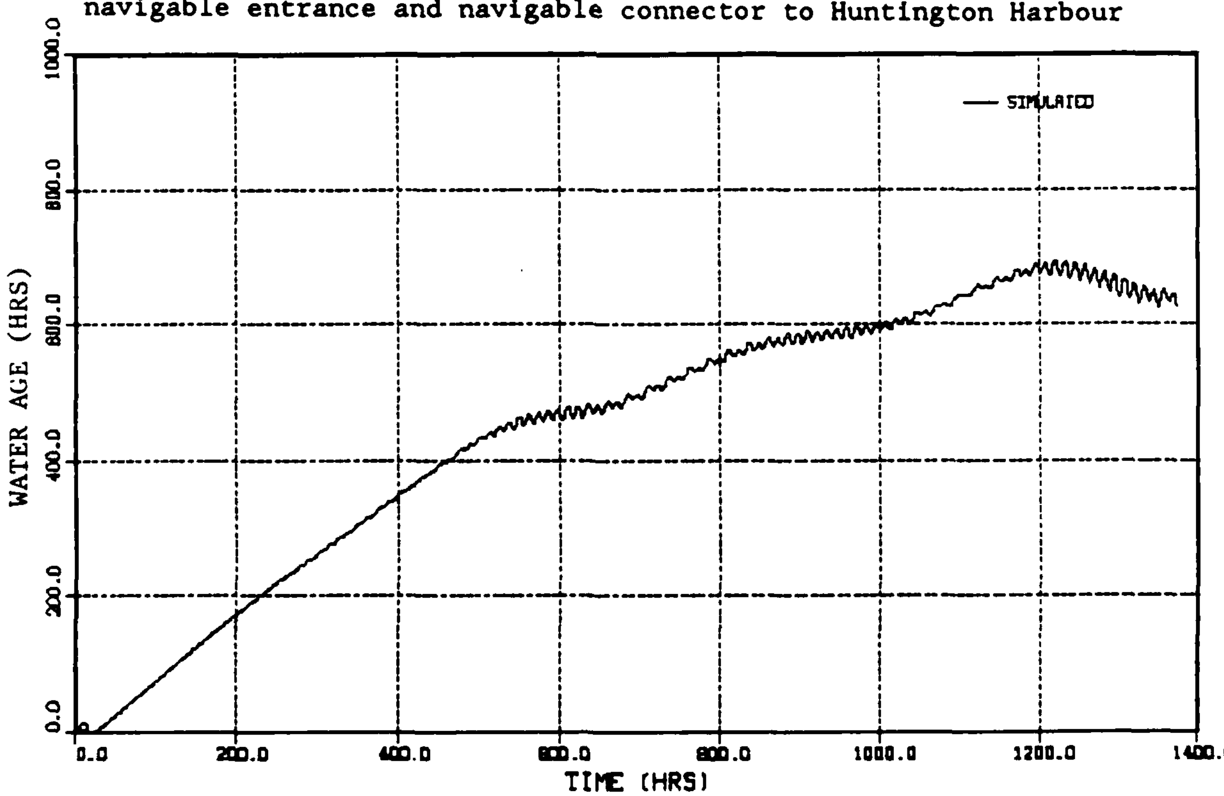


Figure 222. Water age for Node 17, side channel, Huntington Harbour, navigable entrance and navigable connector to Huntington Harbour

sections, and the decrease in velocity would result in decreased mixing which increases the stratification tendency of dissolved oxygen in the water column. This would exacerbate DO problems in Huntington Harbour where observations below DFG standards have been recorded. The decrease in velocity will probably not have a significant impact on the reaeration coefficient. Due to the strong, consistent, land shore breezes, reaeration is wind dominated rather than water velocity controlled. The navigable entrance with a navigable connector could potentially create increased DO stratification and a higher incidence of DO observation near the bottom below the 5 mg/l DFG guidelines in some Huntington Harbour marina areas.

237. For the navigable entrance channel with a non-navigable connector concept, and for the non-navigable entrance configurations, there is a slight decrease in system water age through Huntington Harbour. The shallow depths in Outer Bolsa Bay decrease the flow transport velocity such that the region of low average velocities does not form in the middle of Huntington Harbour.

238. For all of the alternative proposed plan conditions, there is a decrease in the water age in the existing muted tidal wetland areas (Inner Bolsa Bay and the DFG cell). The decrease is slight (10 to 15 percent) for the non-navigable entrance configurations where the entrance is assumed to be closed by littoral transport. The decrease is due to the increase in the number of culverts connecting the existing and proposed tidal wetlands. The decrease is probably not great enough to significantly decrease the environmental stress due to inadequate circulation through the rear wetland areas.

239. For all of the open entrance plans, water age in the interior wetlands is significantly decreased. At all nodes, and for all open entrance conditions, the residence time was significantly lower than observed in the portions of the wetland deemed to be functioning healthfully at the present time (Nodes 37 and 40). For the navigable entrance channel with a navigable connector channel to Huntington Harbour concept, a 40 to 60 percent reduction in the overall residence times is observed in the existing tidal wetlands.

240. Water age in the existing muted tidal wetlands is greater for the navigable entrance than for the non-navigable entrance cases. This is due to two circumstances. First, the navigable entrance connector to the existing wetlands is not located as close to the ocean entrance. Water moves through the marinas and proposed muted tidal wetlands before entering Inner Bolsa Bay.

If a supplemental connector channel is created nearer to the ocean (i.e., connect Node 33 in the marina to Node 37 in Inner Bolsa Bay by a culvert system as per Figure 211), water age is greatly reduced (Table 24). Second, the navigable entrance channel and marina are much deeper than for the non-navigable entrance channel with no marina in this vicinity,. The tidal prism for the navigable entrance condition is a lower percentage of the total water volume which must work its way through the system.

241. For the navigable entrance with a navigable connector channel to Huntington Harbour concept, the introduction of a connector channel between the existing and proposed muted wetland enhancement areas (between Nodes 50 and 134) does not produce an overall improvement in turnover for the interior muted tidal wetlands. With the wetlands connected, a slight increase in the water age in the existing muted wetland areas is balanced by a slight decrease in the water age in the proposed muted wetland areas.

242. For the navigable entrance channel with a non-navigable connector channel to Huntington Harbour concept, water age in the wetlands is somewhat greater than for the navigable entrance channel with a navigable connector channel to Huntington Harbour concept, with a reduction in water age of 35 to 55 percent relative to existing conditions. The impact of the wetland connector channel is the same as observed for the navigable entrance channel with a non-navigable connector channel concept. The inclusion of the wetland connector channel causes a slight increase in the water age in the existing wetland regions, and a decrease in the age in the proposed wetland regions.

243. If the change in the water age from the front to the back of the existing wetlands is compared to the change in water age for the navigable entrance (no wetland connector channel), transport properties are virtually unchanged for both navigable entrance configurations (navigable or non-navigable connector channel to Huntington Harbour). For example, the difference in the average water age is 171 hr between Node 37 (near the front of the existing wetlands) and Node 54 (at the rear of the existing wetlands), 177 hr for the navigable entrance channel with a navigable connector channel, and 181 hr for the navigable entrance channel with a non-navigable connector channel. This reflects the minimal change in water surface elevations in the area for the navigable entrance channel configuration plan from existing conditions (Figures 43 and 29).

244. For all four of the non-navigable entrance channel alternatives, the overall water age is reduced to 20 percent or less of the water age in the existing muted tidal wetlands. The change in water age from the front to the back of the existing muted tidal wetlands (171 hr) is somewhat reduced for the proposed plan concept of no connector channel to the marina and wetlands not connected (113 hr) due to the addition of another culvert system near the ocean. The presence or absence of a non-navigable connector channel to the marina did not affect transport in the wetlands significantly.

East Garden Grove-Wintersburg Flood Control Channel (EGG-WFCC) Runoff

245. To investigate impacts of the various proposed plan alternatives on the transport of runoff from EGG-WFCC into the existing and proposed wetlands, a simulation was performed using the first 200 hr of the tidal signal shown in Figure 210. The model was "warmed up" for 50 hr before constituent simulations were initiated. A runoff inflow with a dissolved tracer (Figure 223) entered the model at the node adjoining EGG-WFCC. For the existing condition, inflow was input at Node 33 (Figure 29); for the proposed alternative navigable entrance channel concepts, inflow was input at Node 83 (Figure 43); and for the proposed alternative non-navigable entrance channel concepts, inflow was input at Node 82 (Figure 83). For the EGG-WFCC runoff tests, the constituent boundaries were established at the edge of the model network (i.e., extending out into the ocean).

246. Five major configurations were compared in this set of simulations, with the following designations identifying displayed data of subsequent figures:

- **A**. Existing conditions,
- **B**. Navigable entrance channel, navigable connector channel to Huntington Harbour, wetlands not connected,
- **C**. Navigable entrance channel, non-navigable connector channel to Huntington Harbour, wetlands not connected,
- **D**. Non-navigable entrance channel, no connector channel to marina, wetlands not connected, and
- **E**. Non-navigable entrance channel closed, no connector channel to marina, wetlands not connected.

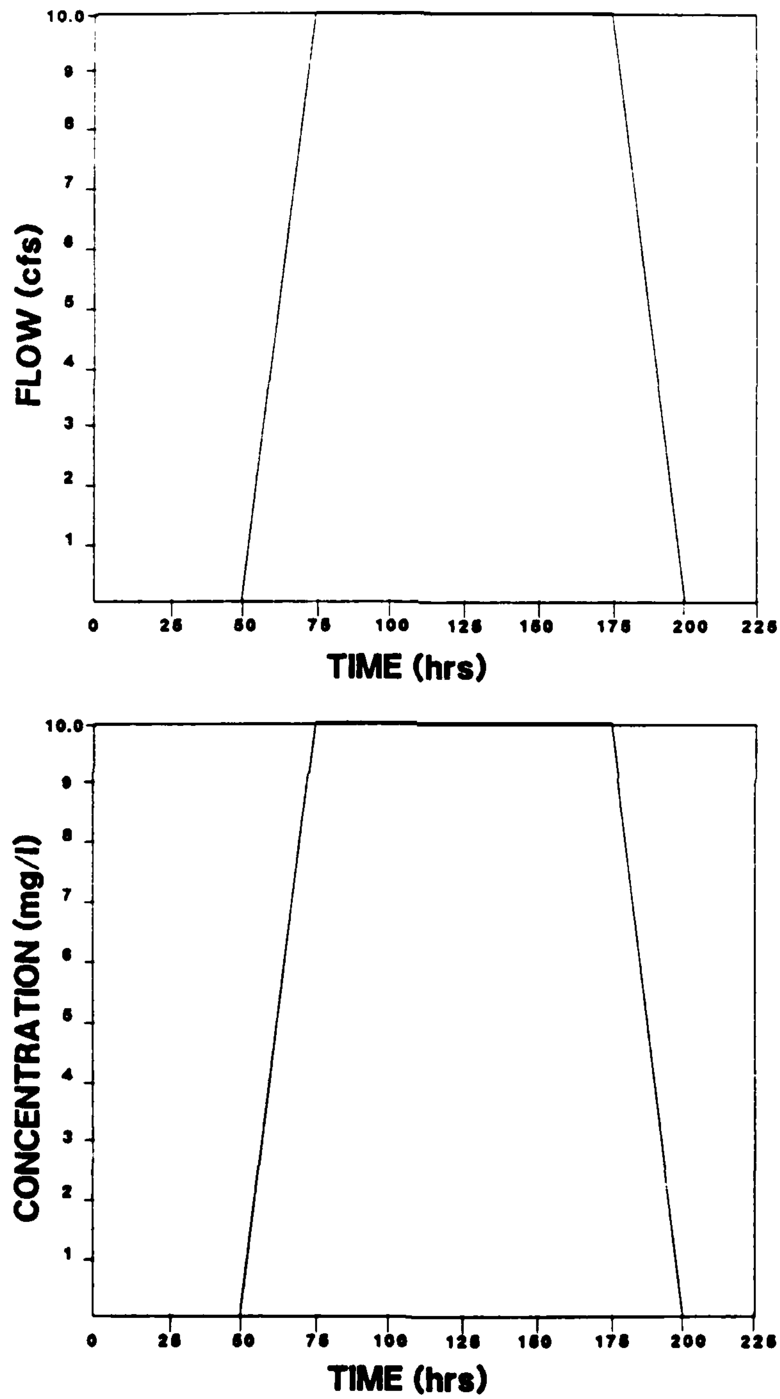


Figure 223. Runoff inflow hydrograph with dissolved tracer to evaluate transport from EGG-WFCC into wetlands

247. Figures 224 and 225 depict the time history of the dissolved tracer in the EGG-WFCC runoff for the five configurations described, at Nodes 40 and 54 located within the existing wetlands. Concentrations into the wetlands are much higher for the existing condition than for any proposed alternative plan concept, including the proposal which considers the complete closing of the non-navigable entrance channel by littoral material in the surf zone. Currently, inflow from EGG-WFCC enters Outer Bolsa Bay immediately in front of the culvert system separating Outer Bolsa Bay and Inner Bolsa Bay. For the existing condition configuration, runoff is swept into Inner Bolsa Bay through the culvert system with little dilution.

248. The location of the wetland culverts at a substantial distance from the channel inflow provides an opportunity for the dilution of the toxicants in the runoff. This effect is most pronounced for the navigable entrance channel configurations (concentrations are about 5 percent of those for existing conditions) where channel runoff flows into a deep, large volume marina area with substantial ocean exchange before flowing into the full tidal wetlands, and then on into the muted tidal wetlands. For the non-navigable

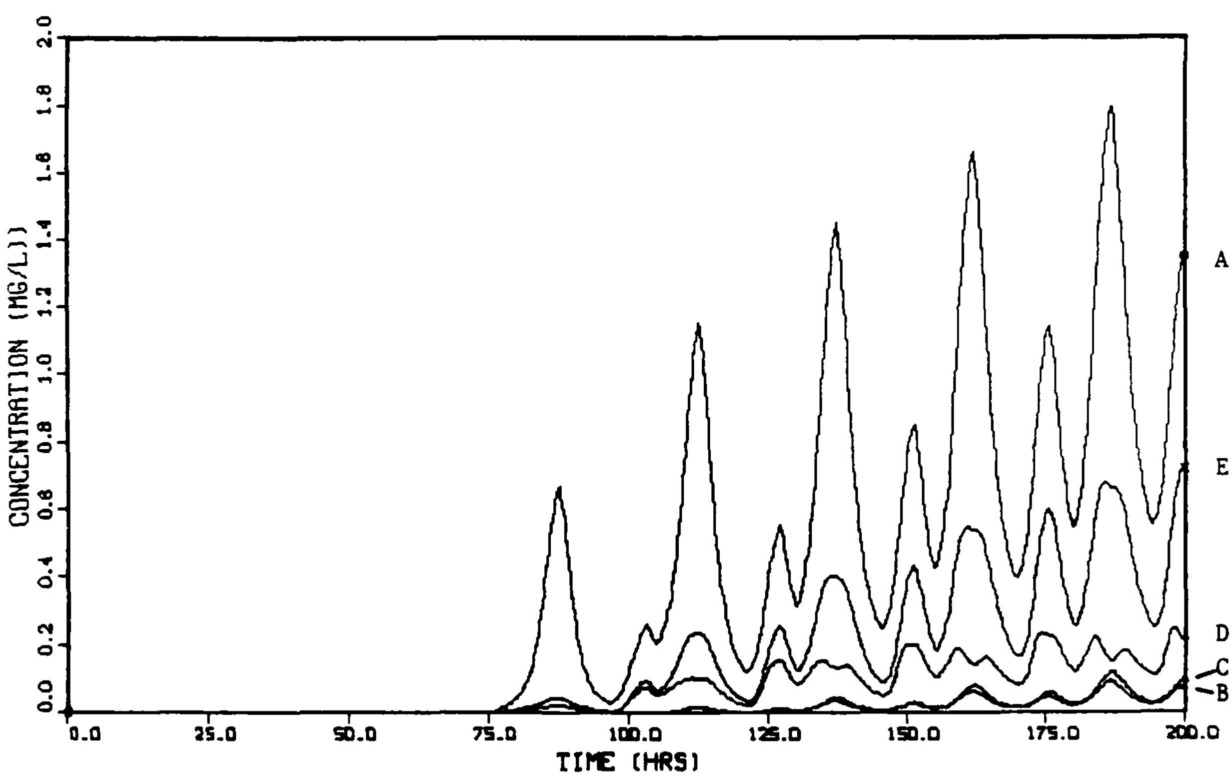


Figure 224. Time history of dissolved tracer from EGG-WFCC runoff at Node 40, Inner Bolsa Bay

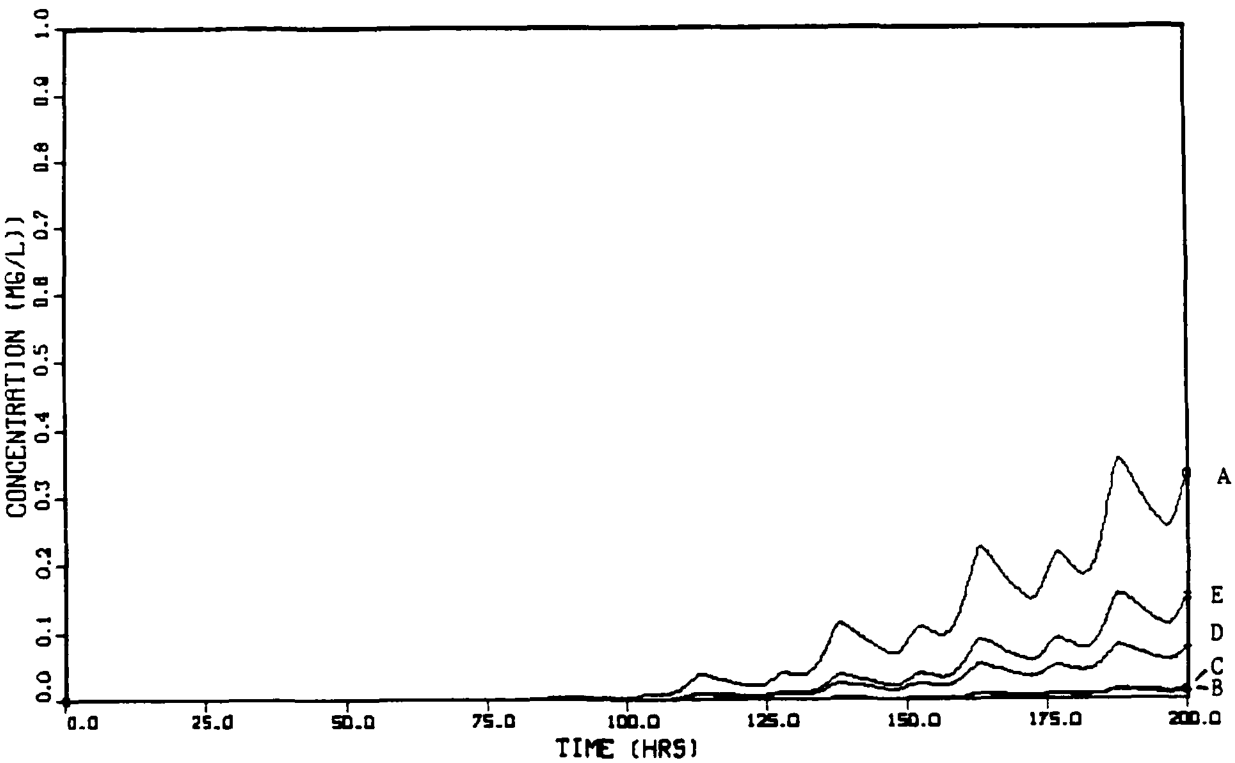


Figure 225. Time history of dissolved tracer from EGG-WFCC runoff at Node 54, DFG muted tidal cell

entrance channel concepts inflow travels a substantial distance to the mouth of the culvert, but with a much smaller dilution volume than the navigable entrance channel concepts, where it is mixed with water from the new entrance. Here, concentrations in the wetlands are 10 to 20 percent of those for existing conditions. If the non-navigable entrance channel closes by littoral material from the surf zone, concentrations are only reduced to 40 to 50 percent of the existing condition concentrations.

249. Concentrations of tracer material entering the proposed muted tidal wetland enhancement regions were compared to the concentrations immediately inside the existing Inner Bolsa Bay muted wetlands (Figure 226). For the proposed navigable entrance channel wetland concepts (curves B and C), the concentrations at Node 117 (just inside the proposed muted tidal wetland from the culvert system) are only a fraction of the concentration observed just inside existing Inner Bolsa Bay at Node 35 (curve A). For the proposed non-navigable entrance channel wetland concept (curve D), the runoff concentrations at Node 87 (just inside the proposed muted tidal wetland from the

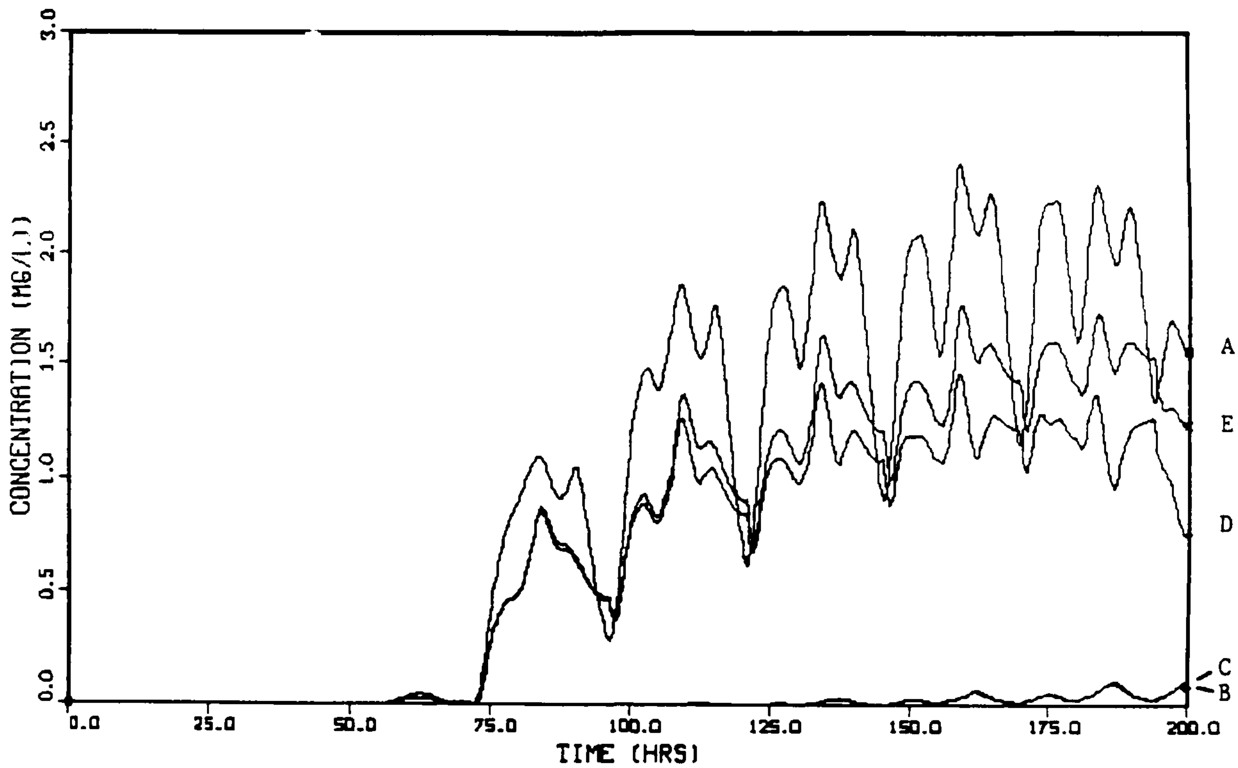


Figure 226. Concentration of dissolved tracer from EGG-WFCC runoff entering proposed muted tidal wetlands compared to concentration just inside existing muted tidal wetland, Inner Bolsa Bay

culvert system) are reduced to only about 50 percent of that presently found in Inner Bolsa Bay immediately beyond the culvert system. For the concept which considers that the non-navigable entrance channel is closed by littoral material, concentrations reach approximately 80 percent of existing condition concentrations. The increased volume of the deep marinas, while they exhibit slightly higher residence time, likewise have a much better capacity to dilute the periodic runoff inflow containing elevated concentrations of contaminants.

Assessment of Transport Characteristics

250. The four major proposed alternatives, (a) navigable entrance channel, navigable connector channel to Huntington Harbour, wetlands not connected, (b) navigable entrance channel, non-navigable connector channel to Huntington Harbour, wetlands not connected, (c) non-navigable entrance channel, non-navigable connector channel to marina, wetlands not connected, and (d) non-navigable entrance channel closed, non-navigable connector channel

to marina, wetlands not connected, all display both distinct positive and negative characteristics with respect to potential impact on water quality in Huntington Harbour, and the existing and enhanced wetland systems.

251. The navigable entrance with a navigable connector channel to Huntington Harbour alternative decreases entry of EGG-WFCC runoff into the existing muted tidal wetlands to a fraction of their current levels while maintaining wetland flushing at current levels. Overall water age in the existing muted wetlands is reduced from present levels for this alternative. The major deleterious effect of this plan is a reduction in flushing in the mid-section of Huntington Harbour where dissolved oxygen resources are limited. Dissolved oxygen in areas of Huntington Harbour is likely to fall below the 5 mg/l standard more frequently than under existing conditions.

252. The navigable entrance with a non-navigable connector channel to Huntington Harbour maintains the current flushing characteristics in Huntington Harbour. The decrease in flushing observed for the navigable connector channel to Huntington Harbour is not observed for the non-navigable connector channel to Huntington Harbour alternative. Overall system residence times in the existing muted tidal wetlands and Bolsa Bay are reduced compared to present conditions. In addition, this alternative plan dilutes EGG-WFCC runoff effectively before it enters the wetlands.

253. The non-navigable entrance channel alternatives do not adversely impact flushing in Huntington Harbour. Overall system residence times in both the existing and proposed wetland enhancement areas of Bolsa Bay are reduced to a greater degree than for the navigable entrance channel alternatives. Movement of EGG-WFCC runoff into the existing muted tidal wetland region is substantially reduced, although not to quite the same extent as for the navigable entrance channel alternatives. Runoff from EGG-WFCC into the non-navigable entrance channel concept proposed muted tidal wetlands is somewhat less than into the existing muted tidal wetlands, but such inflows may be high enough to have a deleterious affect on these wetlands.

PART XIII: SUMMARY AND CONCLUSIONS

Summary

Tidal circulation modeling

254. The purposes of the tidal circulation computer simulation modeling task were to ascertain the hydrodynamic effects relating to the development of a proposed new navigable entrance channel to Bolsa Bay with associated marinas and wetland enhancement (termed the Preferred Alternative by the County of Orange and the California Coastal Commission), both with and without a navigable connector channel to Huntington Harbour. The effects of a non-navigable entrance channel to Bolsa Bay with associated marinas and wetland enhancement (termed the Secondary Alternative by the County of Orange and the California Coastal Commission), both with and without a by-pass channel connecting the East Garden Grove-Wintersburg Flood Control Channel (EGG-WFCC) with a proposed marina near existing Warner Avenue, also were ascertained. Additionally, the hydrodynamic effects resulting from the closure of the Secondary Alternative non-navigable entrance channel concept by littoral material transport in the surf zone were determined. The hydrodynamic phenomena pertaining to each of these alternative concepts include tidal water surface elevation fluctuations and maximum average channel velocities in the Anaheim Bay complex, Huntington Harbour, Outer Bolsa Bay, Inner Bolsa Bay, the California Department of Fish and Game (DFG) muted tidal cell, entrance channels, marinas, and all wetland development proposed for enhancement and improvement of the existing biological reserves.

Transport simulation and water quality assessment

255. The purposes of the transport computer simulation and water quality assessment included assembling and synthesizing existing water quality data, and collecting supplemental water quality data, for calculating any potential changes to transport and dispersion of conservative tracers from existing conditions by proposed navigable and non-navigable entrance channels. An evaluation of the quality of the present water supply provided by existing conditions in the ecological reserve with the quality of water to be provided with the proposed navigable and non-navigable entrance channels and wetland

enhancement concepts, both in terms of water quality parameters and water parcel residence times, also was performed. The effects of proposed enhancements on water quality in the Anaheim Bay complex, Huntington Harbour, existing full and muted tidal wetlands, proposed full and muted tidal wetlands, and flushing capability of proposed wetland modifications, were ascertained.

Conclusions

Anaheim Bay wetlands

256. Presently, tidal flows from the Pacific Ocean flow through the Anaheim jetties and branch to either Anaheim Bay or Huntington Harbour. That flow which presently supports Outer Bolsa Bay, Inner Bolsa Bay, and the DFG muted tidal cell must traverse through Huntington Harbour. Because the Anaheim jetty entrance is large and offers essentially no restriction to transport into the Anaheim Bay and Huntington Harbour region, and since flow to the existing and proposed full and muted tidal wetlands does not pass through Anaheim Bay, any modifications created by either the Preferred Alternative or the Secondary Alternative will have no impact on water levels in the existing Anaheim Bay wetlands.

Huntington Harbour

257. Tidal elevations. The navigation channels in the Huntington Harbour complex are relatively wide and deep, thus conveying a sufficient volume of tidal flow to allow the harbor water surface elevations to respond almost precisely as the ocean tide. Because the harbor is presently able to respond in such a manner, it will continue to respond almost precisely with the ocean tide regardless of any modifications pertaining to a new entrance channel design and/or wetland enhancement configurations. Water surface elevations in Huntington Harbour will be unaffected by changes in Bolsa Bay.

258. Velocities. Because all tidal flows to support the existing wetlands must pass through Huntington Harbour, average channel velocities in the harbor are presently sufficient to provide relatively good flushing and water turnover characteristics. The navigable entrance channel concept with a navigable connector channel to Huntington Harbour will transport a large

portion of the tidal prism of Huntington Harbour (which presently comes from the ocean entrance at Anaheim). The navigable entrance channel with a navigable connector channel to Huntington Harbour concept will cause flow to enter and leave the harbor from both the eastern and western directions, and a zone of reduced average channel velocities in Huntington Harbour may result, (Table 26).

259. Average channel velocities provide a qualitative indication of the effect of a proposed plan on existing conditions, but other pertinent phenomena exist which significantly affect transport and dispersion of water body constituents. Velocity profiles and gradients at a channel section, circulation and mixing caused by the California coastal sea breeze, non-periodic ocean tides, and non-linear bottom friction, make it virtually impossible for a stationary line of stagnation to develop in Huntington Harbour or any other similar real world situation.

Wetlands

260. Existing wetlands condition. Under existing conditions, Outer Bolsa Bay tide rises to almost the same elevation as the Huntington Harbour tide (4.1 ft), but falls to only about 65 percent of the low water elevation (2.7 ft), for spring tide conditions (range = 6.8 ft). Under the conditions (ocean range = 8.2 ft), the Inner Bolsa Bay tide range (1.5 ft) is reduced to approximately 22 percent of the Outer Bolsa Bay tide range. The DFG muted tidal cell tide range (1.1 ft), is reduced to approximately 73 percent of Inner Bolsa Bay tide range due to the box culvert connector. For present conditions, Pacific Ocean spring tide range = 8.2 ft, Outer Bolsa Bay spring tide range = 6.8 ft, Inner Bolsa Bay spring tide range = 1.5 ft, DFG muted tidal cell spring tide range = 1.1 ft.

261. Proposed wetlands geometry and tide gate system. SLC specified that minimal earth moving should be performed to the bottom topography for both the Preferred Alternative and Secondary Alternative wetland enhancement regions. While specific wetland contour designs have not been developed at this time, the wetlands should approximate certain elevation-area relationships based on Inner Bolsa Bay or other satisfactory wetland areas. The topography necessary to simulate these relationships was introduced into the

Table 26

Comparison of Existing Conditions
with
Proposed Alternative Plan Concepts

Maximum Average Channel Velocities Along Main Channel System

Location	Link No	POSTBOL	NENC1	NENNC1	NNECC1	NNECC4	NOENT1	NOENT2
Pacific Coast Highway bridge	2	2.78	1.41	2.44	2.82	2.82	3.13	3.10
Huntington Harbour	5	1.42	0.49	1.24	1.53	1.53	1.74	1.69
Huntington Harbour	7	1.48	0.39	1.30	1.63	1.60	1.84	1.78
Huntington Harbour	10	0.71	0.09	0.62	0.79	0.79	0.92	0.89
Huntington Harbour	17	0.66	0.05	0.57	0.74	0.73	0.87	0.83
Huntington Harbour	24	0.57	0.27	0.45	0.69	0.66	0.83	0.79
Huntington Harbour	25	0.30	0.35	0.21	0.39	0.37	0.50	0.47
Huntington Harbour	26	0.34	0.59	0.18	0.48	0.45	0.63	0.58
Warner Avenue bridge	34	1.65	0.72	0.85	0.51	0.47	0.74	0.67
Outer Bolsa Bay	35	1.35	0.67	0.37	1.13	1.35	1.49	2.46
Outer Bolsa Bay	36	0.71	0.71	0.40	0.65	0.76	0.84	1.18
Outer Bolsa Bay	37	0.88	0.75	0.54	0.51	0.62	0.90	1.30
Outer Bolsa Bay	38	1.12	0.60	1.35	0.90	1.09	1.23	1.79
Non-navigable entrance channel	90	----	----	----	1.33	1.35	----	----
East Garden Grove-Wintersburg Flood Control Channel	94	----	----	----	0.57	0.53	0.41	0.29
Channel to muted wetlands	97	----	----	----	1.40	1.39	1.22	0.94
Navigable entrance channel	109	----	0.44	0.38	----	----	----	----
By-pass channel to marina	89	----	----	----	1.31	----	2.18	----
By-pass channel to marina	162	----	----	----	1.82	----	3.16	----

POSTBOL = existing conditions
NENC1 = navigable entrance, navigable connector to Huntington Harbour
NENNC1 = navigable entrance, existing connector to Huntington Harbour
NNECC1 = non-navigable entrance, by-pass channel to marina
NNECC4 = non-navigable entrance, no by-pass channel to marina
NOENT1 = entrance channel closed, by-pass channel to marina
NOENT2 = entrance channel closed, no by-pass channel to marina

numerical model. The tide gate and culvert systems to be utilized in the model operation also were specified by SLC. Both the wetland designs, and the tide gate and culvert systems, are distinctly different depending on whether the alternative is a navigable entrance or a non-navigable entrance concept. The hydraulic connections between the Pacific Ocean and the wetlands, the wetland design, and the culvert system design and operation, can be optimized to provide any reasonable degree (within maximum limits) of tidal muting, flooding, and inundation to support marine life and vegetation varieties.

Bolsa Bay tides

262. Navigable entrance, navigable channel to Huntington Harbour. The navigable entrance channel concept with the culvert system specified by SLC provides for about a 51 percent reduction of the tide range in the proposed full tidal wetland region (range = 4.0 ft) from that of the ocean (range = 8.2 ft). The second set of culverts provides for about another 55 percent reduction in tide range between the proposed full tidal wetlands (range = 4.0 ft) and the proposed muted tidal wetlands (range = 1.8 ft), thus indicating about a 78 percent reduction in tide range between the ocean and the proposed muted tidal wetlands. About a 26 percent increase in tide range in Inner Bolsa Bay (range = 1.9 ft) and the DFG muted tidal cell (range = 1.4 ft) over present conditions (1.5 ft and 1.1 ft, respectively) will result regardless of whether the existing and proposed muted tidal wetlands are connected to each other. The effects of such a wetlands connection are imperceptible, and the Pacific Ocean spring tide range = 8.2 ft, Outer Bolsa Bay spring tide range = 8.1 ft, Inner Bolsa Bay spring tide range = 1.9 ft, DFG muted tidal cell spring tide range = 1.4 ft, proposed full tidal wetland spring tide range = 4.0 ft, and proposed muted tidal wetland spring tide range = 1.8 ft, (Table 27).

263. Navigable entrance, existing channel to Huntington Harbour. Tidal response throughout the entire system is effectively the same for a non-navigable connector channel to Huntington Harbour as for a navigable connector channel.

Table 27

Comparison of Existing Conditions
with
Proposed Alternative Plan Concepts

Water Surface Elevations in Existing and Proposed Wetlands

Wetlands Connected

Location	Node No	POSTBOL	NENC1	NENNC1	NNECC3	NNECC4	NOENT3	NOENT4
				Spring High Tide, feet (msl)				
Huntington Harbour	10	4.10	4.10	4.10	4.10	4.10	4.10	4.10
Outer Bolsa Bay	31	4.10	4.10	4.10	4.10	4.10	4.10	4.10
Inner Bolsa Bay	37	1.04	1.40	1.40	1.15	1.15	1.15	1.15
DFG muted tidal cell	54	0.98	1.34	1.34	1.10	1.10	1.10	1.10
Proposed full tidal wetlands	93	----	3.08	3.08	----	----	----	----
Proposed muted tidal wetlands	123	----	1.41	1.41	----	----	----	----
Proposed muted tidal wetlands	95	----	----	----	1.14	1.14	1.11	1.11
				Spring Low Tide, feet (msl)				
Huntington Harbour	10	-4.10	-4.10	-4.10	-4.10	-4.10	-4.10	-4.10
Outer Bolsa Bay	31	-2.77	-4.02	-4.05	-3.50	-3.36	-2.00	-2.70
Inner Bolsa Bay	37	-0.40	-0.43	-0.40	-0.30	-0.31	-0.30	-0.30
DFG muted tidal cell	54	-0.09	0.01	0.01	0.02	-0.02	0.00	0.00
Proposed full tidal wetlands	93	----	-0.86	-0.86	----	----	----	----
Proposed muted tidal wetlands	123	----	-0.39	-0.39	----	----	----	----
Proposed muted tidal wetlands	95	----	----	----	-0.32	-0.32	-0.30	-0.30
				Spring Tidal Range, feet				
Huntington Harbour	10	8.2	8.2	8.2	8.2	8.2	8.2	8.2
Outer Bolsa Bay	31	6.8	8.1	8.1	7.6	7.4	6.1	6.8
Inner Bolsa Bay	37	1.5	1.9	1.9	1.4	1.4	1.4	1.4
DFG muted tidal cell	54	1.1	1.4	1.4	1.1	1.1	1.1	1.1
Proposed full tidal wetlands	93	---	4.0	4.0	---	---	---	---
Proposed muted tidal wetlands	123	---	1.8	1.8	---	---	---	---
Proposed muted tidal wetlands	95	---	---	---	1.5	1.5	1.4	1.4

POSTBOL = existing conditions
NENC1 = navigable entrance, navigable connector to Huntington Harbour
NENNC1 = navigable entrance, existing connector to Huntington Harbour
NNECC3 = non-navigable entrance, by-pass channel to marina
NNECC4 = non-navigable entrance, no by-pass channel to marina
NOENT3 = entrance channel closed, no by-pass channel to marina
NOENT4 = entrance channel closed, by-pass channel to marina

264. <u>Non-Navigable entrance, by-pass channel to marina.</u> The non-navigable entrance channel concept with the culvert system again specified by SLC provides for about an 83 percent reduction in tide range in the proposed muted tidal wetlands (range = 1.4 ft) from that of the ocean (range = 8.2 ft). While this is a slightly greater reduction in tide range for these proposed muted tidal wetlands (1.4 ft) than for the proposed muted tidal wetlands of the navigable entrance channel concept (1.8 ft), a different arrangement and operation of the tide gates and culvert system can produce any reasonable desired level of tidal reduction in either proposed wetland system (within maximum limits). Essentially no changes occur to the tidal range of Inner Bolsa Bay (1.4 ft) and the DFG muted tidal cell (1.1 ft) from present conditions when the existing and proposed muted tidal wetlands are connected, although both high and low tide elevations are increased about 0.1 ft. If the existing and proposed muted tidal wetlands are not connected, about a 25 percent increase in tide range will occur over present conditions. For the existing and proposed muted tidal wetlands connected situation, Pacific Ocean spring tide range = 8.2 ft, Outer Bolsa Bay spring tide range = 7.6 ft, Inner Bolsa Bay spring tide range = 1.4 ft, DFG muted tidal cell spring tide range = 1.1 ft, and proposed muted tidal wetlands spring tide range = 1.5 ft.

265. <u>Non-navigable entrance, no by-pass channel to marina.</u> Tidal response throughout the entire system is effectively the same with or without a by-pass connector channel to the proposed marina, except for low tide elevation in Outer Bolsa Bay which remains about 0.2 ft higher than when a by-pass channel exists.

266. <u>Non-navigable entrance closed, by-pass channel to marina.</u> Concern exists regarding whether the non-navigable entrance channel will remain open under the shoaling effects of littoral material in the surf zone. For purposes of this investigation, it was assumed the channel would close completely. For this condition, low water elevations in Outer Bolsa Bay do not fall below -2.5 to -2.7 ft msl, even though the tide in Huntington Harbour falls to -4.1 ft msl at low spring events. For the culvert system specified, tidal elevations in the propose muted tidal wetlands are reduced insignificantly (around 3 percent) from that tide range when the non-navigable entrance

channel remains open. Warner Avenue bridge opening will be significantly enlarged, and offer minimal flow constriction. Spring high tide will rise to about +4.1 ft msl in Outer Bolsa Bay. High tides in Inner Bolsa Bay, the DFG muted tidal cell, and the proposed muted tidal wetlands, will be maintained by the Outer Bolsa Bay high tide which is not reduced by the entrance channel closure. Low tides in the existing and proposed muted tidal wetlands are determined by flow through the culverts, which can be discharged equally as well entirely through Outer Bolsa Bay or partially through Outer Bolsa Bay and partially through the open non-navigable entrance. For the wetlands connected situation, Pacific Ocean spring tide range = 8.2 ft, Outer Bolsa Bay spring tide range = 6.8 ft, Inner Bolsa Bay spring tide range = 1.4 ft, DFG muted tidal cell spring tide range = 1.1 ft, and proposed muted tidal wetlands spring tide range = 1.4 ft.

267. Non-navigable entrance closed, no by-pass channel to marina. For the condition of closure of the non-navigable entrance channel and no by-pass channel to the marina, low tide in Outer Bolsa Bay can not fall as low as when both conveyance channels are responding to the tide level in Huntington Harbour. Outer Bolsa Bay simply does not drain as low as when two channels are operational. Tidal response throughout the entire system is effectively the same with or without a by-pass connector channel to the proposed marina, except for low tide elevation in Outer Bolsa Bay which remains about 0.7 ft higher than when a by-pass channel exists.

Bolsa Bay velocities

268. Maximum channel velocities are important from the standpoint of navigation, swimmer safety, transport and flushing for satisfactory water quality, and potential for scour and erosion in the wetlands and around bridge abutments. Maximum average channel velocities for existing conditions, and for all proposed alternative concepts, are presented in Table 26.

269. Pacific Coast Highway bridge. Concern exists regarding the effects of strong currents on navigation craft which occasionally have difficulty entering and exiting Anaheim Bay at the Pacific Coast Highway bridge. Helical and spiral flow created by the velocity field at the relatively sharp

curves approaching the PCH bridge where craft are required to maneuver tend to create a hazardous situation. Potential increases in velocity under the PCH bridge due to any increase in tidal prism for nourishing wetland areas are of significant interest to navigation. Because a portion of the Huntington Harbour tidal prism enters from the proposed new navigable entrance channel, the navigable entrance with navigable connector to Huntington Harbour concept results in about a 50 percent reduction in maximum average velocities at the PCH bridge (from 2.78 to 1.41 ft per sec). The navigable entrance with existing connector to Huntington Harbour concept, and also the non-navigable entrance concept, results in velocities under PCH bridge of about the same magnitude as existing conditions (2.44, and 2.82 ft per sec, respectively). Only the condition in which the non-navigable entrance channel closes results in an increase in velocities at this location of about 13 percent (from 2.78 to 3.13 ft per sec).

270. Huntington Harbour. As previously discussed, the navigable entrance with navigable connector to Huntington Harbour concept contributes to a region of reduced average velocities in the harbor. The navigable entrance with existing connector to Huntington Harbour concept induces velocities in the harbor which are slightly (15 percent) less than existing conditions, (1.30 and 1.48 ft per sec, respectively). A portion of the tidal prism of the proposed wetlands for the non-navigable entrance concept passes through Huntington Harbour. This results in an increase of maximum average velocities of about 10 percent in Huntington Harbour over existing conditions for the non-navigable entrance concept (from 1.48 to 1.63 ft per sec). The non-navigable entrance closed concept requires all wetland tidal prism to pass through Huntington Harbour. There results an increase of maximum average velocities up to 24 percent (from 1.48 to 1.84 ft per sec) in Huntington Harbour over existing conditions for the non-navigable entrance closed situation.

271. Warner Avenue bridge. All proposed alternative concepts (except the navigable entrance with existing connector to Huntington Harbour) provide for relocating and significantly increasing the bridge opening size (width and depth) at Warner Avenue. Velocities at this location for these conditions are

reduced at least 55 percent (from 1.65 to a maximum of 0.74 ft per sec). Because the navigable entrance with existing connector to Huntington Harbour conveys only a small portion of the harbor tidal prism, average channel velocities at Warner Avenue bridge are also reduced for this concept by about 48 percent (from 1.65 to 0.85 t per sec). Accordingly, velocities at Warner Avenue bridge are significantly reduced for all alternative scenarios, at least a minimum reduction of 48 percent (from 1.65 to 0.85 ft per sec).

272. Outer Bolsa Bay. Concern exists regarding the potential for scouring velocities to develop in Outer Bolsa Bay, with resulting shoaling in Huntington Harbour. Maximum average channel velocities in existing Outer Bolsa Bay are not exceeded by either the navigable entrance or the non-navigable entrance concepts. Hence, the by-pass connector channel to the marina is not necessary (if the non-navigable entrance remains open). If the non-navigable entrance closes, maximum average velocities up to 2.46 ft per sec will result in Outer Bolsa Bay and may scour sediments from the bay as this material consists of silty sands and clayey sands (Woodward-Clyde Consultants 1987). If the by-pass channel exists, these velocities will be reduced to about 1.49 ft per sec. However, the non-navigable entrance could be reopened immediately following a storm to alleviate potential scouring velocities in Outer Bolsa Bay. Potential scour in Outer Bolsa Bay could be prevented by various channel stabilization measures provided as part of project construction.

273. By-pass channel to marina. The above notwithstanding, if the by-pass channel to the marina is installed, maximum average channel velocities in the channel itself will reach 3.16 ft per sec; hence, by-pass channel stabilization measures should be included as part of project construction.

EGG-WFCC 100-year flood flow, 9,710 cfs

274. Concern exists regarding the maximum flood flow elevations and excessive velocities which may be reached in Huntington Harbour, the proposed marina, and the wetlands by the 100-year flood, for both existing conditions and various alternative proposed plans for wetland enhancement. Levee elevations with adequate freeboard must be established to preclude

overtopping. It is considered that all culvert systems will function during flood conditions in the same manner as during normal tidal cycles; i.e., the culverts will not be closed to prevent flood flow from entering the wetlands.

275. Existing condition, water surface elevations. Under existing conditions, all flood flow will be required to pass through Outer Bolsa Bay and Huntington Harbour. Warner Avenue bridge acts as a barrier to the passage of the 100-year flood discharge, flow is retarded by the bridge constriction, and ponding occurs in Outer Bolsa Bay, reaching a maximum water surface elevation of 7.1 ft, an increase beyond the normal spring high tide elevation of about 3.0 ft. Because of the elevated water surfaces in Outer Bolsa Bay, flooding of Inner Bolsa Bay occurs, where the maximum water surface elevation increases to around 6.7 ft from around 1.0 ft. A similar increase in water surface elevation occurs in the DFG muted tidal cell. The wide, highly efficient conveyance channels of Huntington Harbour allow the passage of the flood flow with only minimal increase in maximum water surface elevation of about 0.3 ft, from about 4.1 ft to about 4.4 ft.

276. Navigable entrance, existing channel to Huntington Harbour, water surface elevations. The 100-year flood flow is insignificant with respect to the capacity of the navigable entrance to convey this volume. The flood flow will pass directly through the proposed marina and into the Pacific Ocean. Maximum water surface elevations in Huntington Harbour and Outer Bolsa Bay will be unaffected. Inner Bolsa Bay will experience an increase beyond normal spring tides of about 0.5 ft, from about 1.0 ft. The DFG muted tidal cell will experience an increase of about 0.4 ft, from about 1.0 ft. The maximum water surface elevations in both the proposed full tidal and muted tidal wetland regions will increase only about 0.1 ft.

277. Non-navigable entrance, no by-pass channel to marina, water surface elevations. An increase in water surface slope develops across Outer Bolsa Bay from Warner Avenue bridge to the proposed new entrance, increasing by about 0.4 ft and creating a maximum water surface elevation of about 4.5 ft. Inner Bolsa Bay and the DFG muted tidal cell will experience flooding, and an increase in maximum water surface elevation of about 2.5 ft, from

about 1.0 ft to about 3.5 ft. The proposed muted tidal wetlands will experience about a 2.4 ft increase in maximum water surface elevation, from about 1.1 ft to about 3.5 ft.

278. Non-navigable entrance closed, no by-pass channel to marina, water surface elevations. A situation analogous to the existing condition results. Huntington Harbour will experience an increase in maximum water surface elevation of about 0.3 ft, from 4.1 ft to 4.4 ft. Outer Bolsa Bay will achieve a maximum water surface elevation of about 5.4 ft at the previous non-navigable entrance location. Inner Bolsa Bay and the DFG muted tidal cell will experience flooding with an increase in maximum water surface elevation beyond normal spring tides of about 3.9 ft, from about 1.0 ft to about 4.9 ft. The proposed muted tidal wetlands also will flood to the same elevations.

279. Existing condition, velocities. While the maximum water surface elevations throughout Huntington Harbour are not significantly greater under the 100-year flood flow conditions, maximum average channel velocities occur near mean tide elevations when the flow cross-sectional areas are less than maximum. Hence, tidal flow and flood flows are being conveyed simultaneously through a minimum area and, thus, at a maximum velocity. Maximum average channel velocities increase at the Pacific Coast Highway bridge from about 2.8 to about 5.0 ft per sec (80 percent increase). Maximum average channel velocities in Huntington Harbour increase up to a maximum 3.5 ft per sec from about 1.5 ft per sec (130 percent increase). Other sections of the harbor experience a greater percentage increase, although not as large an absolute magnitude. Warner Avenue bridge vicinity experiences excessively high velocities due to the large difference in water levels across the bridge opening. Maximum average velocities increase from about 1.6 to about 11.6 ft per sec (600 percent increase). Outer Bolsa Bay will experience velocities approaching 2.8 ft per sec, which would be significantly greater if not for the ponding effect created by the Warner Avenue bridge.

280. Navigable entrance, existing channel to Huntington Harbour, velocities. This concept allows all flood flow to exit from the Bolsa Bay complex directly into the Pacific Ocean with minimal (imperceptible) hydrodynamic effects on the system. Velocities through Huntington Harbour and Outer Bolsa Bay are reduced below normal spring tide values (except for the link immediately adjacent to the proposed new entrance channel). From the hydrodynamic standpoint, this concept best and effectively reproduces existing condition spring tide effects through Huntington Harbour and Outer Bolsa Bay.

281. Non-navigable entrance, no by-pass channel to marina, velocities. Maximum average channel velocities at Pacific Coast Highway bridge increase from about 2.8 to about 4.0 ft per sec (40 percent increase), while velocities in Huntington Harbour increase from about 1.5 to about 2.6 ft per sec (70 percent increase). Because of the limited size of the non-navigable entrance channel, velocities through Outer Bolsa Bay increase from about 1.4 to about 5.7 ft per sec at a restricted link near Warner Avenue bridge.

282. Non-navigable entrance closed, no by-pass channel to marina, velocities. If the non-navigable entrance channel is permitted to close, maximum average channel velocities throughout the Bolsa Bay system under flood flow conditions will increase beyond those values estimated when the entrance is maintained open. In both cases, scouring velocity magnitudes will exist in Outer Bolsa Bay, and resulting shoaling will occur in the eastern portion of Huntington Harbour. Maximum average channel velocities will approach 5.2 ft per sec at the Pacific Coast Highway Bridge, 3.6 ft per sec at Link 7 in Huntington Harbour, and 6.9 ft per sec at Link 35 in Outer Bolsa Bay. However, the entrance channel could be reopened immediately following a storm to alleviate excessively high velocities throughout Bolsa Bay. Even if the 100-year flood occurred and the proposed entrance channel at Bolsa Chica were not reopened immediately, scour expected to result from high velocities could be prevented by various channel stabilization measures provided as part of project construction.

Tide phase lag between Bolsa Bay and Anaheim Bay

283. Long-term tide gages (with more than 19 years of measurements) are located at Newport Bay entrance (Station 9410580) and at Los Angeles outer harbor (Station 9410660). Time differences between tides were obtained from the National Ocean Survey. The time differences are typically accurate to 0.1 hr (6 min). Based on measurements between 1960 and 1978, high tide occurs at Newport Bay entrance 3 min before occurring at Los Angeles outer harbor, and low tide occurs 2 min early. The distance between Newport Bay entrance and Los Angeles outer harbor is approximately 21 nm. The distance between the location of the proposed new entrance at Bolsa Bay and the Anaheim Bay entrance jetties is approximately 2.7 nm, or about 13 percent of the distance between the two tide gage locations. Hence, the high tide phase lag between the proposed new Bolsa Bay entrance location and Anaheim Bay entrance is approximately 23 sec, with the low tide phase lag being about 16 sec.

284. For all hydrodynamic simulations, identical tides were applied simultaneously at both the Anaheim Bay jetties and the proposed new Bolsa Bay entrance channel location. Resulting average channel velocities are considered to exist over an entire channel length, when in reality those velocities occur over only a finite small channel length (as the channel length is reduced in the limiting process to a small value). To ascertain the effects of a phase lag between these two entrances on hydrodynamics (particularly in Huntington Harbour, where a region of reduced velocities may be created by a navigable entrance with a navigable connector to the harbor), a 20-sec phase lag was applied for this concept and resulting velocities were observed in Huntington Harbour.

285. It was determined that the precise location of the region of reduced velocity is governed by the phase lag, and a 20-sec phase lag introduced into the numerical model will minimally displace the region in a westerly direction. Slightly more of the Huntington Harbour tidal prism will enter the system from the proposed new entrance channel than indicated by the no-lag condition. The specific location of the region of reduced velocities can be known only by reformulating the link-node system with finite small channel lengths. The channel lengths of the present link-node system formulation are excessively large (Link 5 = 1,500 ft, Link 7 = 1,250 ft, Link 10 = 1,150) for resolving such precisely small spatial locations. This fact was not known

a priori when the link-node system which satisfies all other aspects of the investigation was formulated.

Breaking wave setup in the surf zone

286. Wave setup is the superelevation of the mean water elevation due to the onshore mass transport of the water by breaking wave action alone. This phenomenon is related to the conversion of kinetic energy of wave motion to a quasi-steady potential energy. Wave setup is a phenomenon involving the action of a train of many waves over a sufficient period of time to establish an equilibrium water level condition. The exact amount of time for equilibrium to be established is unknown, but a duration of 1 hr is considered an appropriate minimum value. When a storm of duration longer than 1 hr approaches a coastline where significant structural features exist (e.g., a nuclear power plant), wave setup in the nearshore zone may become important. Wave setup is estimated from laboratory investigations to be about 15 percent of the still water breaking depth. Representative values of breaking wave setup in the surf zone are 1- to 2-ft increase in tide elevation. Final engineering design of flood channel dikes and wetland boundaries should consider the effects of wave setup at the proposed new entrance.

Presently existing water quality assessment

287. Three categories of water quality problems presently existing or potentially arising need to be considered in evaluating impacts of proposed alternatives to develop and enhance the wetlands of Bolsa Bay.

288. First, dissolved oxygen concentrations are violated occasionally in Bolsa Bay, and in the deeper waters of Huntington Harbour, during the summer months. An additional ocean entrance will provide a source of water with higher dissolved oxygen concentrations. However, additional development will potentially increase biological oxygen demand (BOD) sources to the area (increased vessel wastes and runoff).

289. Second, certain trace metals and organic toxicants are detected in sediments throughout the area. Trace metals appearing at elevated levels in the sediments include lead, zinc, arsenic, and cadmium. Accumulation of these metals in fish and wildlife presents a potential human health hazard as well as threatening a thriving wildlife population. Chlordane and organochlorine

pesticide residues are detected throughout Huntington Harbour and Bolsa Bay. TBT is observed in localized portions of Huntington Harbour, but appears to be relatively immobile. Use of TBT has recently been prohibited and, therefore, the impacts and concentrations occurring in the system should decline in the future. Increased flushing with an additional ocean entrance will tend to mediate sediment problems associated with system toxicants.

290. Third, low flushing of the existing wetlands has resulted in stagnation conditions in the most-interior portions of the wetlands. Primary productivity within the wetlands may be nutrient-limited without sufficient tidal exchange. Under present conditions (only one entrance to the existing wetlands), increasing tidal exchange (creation of Inner Bolsa Bay and the DFG muted tidal cell) appears to have resulted in an increase in toxicant levels in the existing wetland areas. This situation will be significantly improved with an additional ocean entrance.

Assessment of transport characteristics

291. The four major proposed alternatives (a) navigable entrance channel, navigable connector channel to Huntington Harbour, (b) navigable entrance channel, existing connector to Huntington Harbour, (c) non-navigable entrance channel, and (d) non-navigable entrance channel closed, all display both distinct positive and negative characteristics with respect to potential impact on water quality in Huntington Harbour and the enhanced wetland system.

292. The navigable entrance with a navigable connector channel to Huntington Harbour alternative decreases entry of EGG-WFCC runoff into the existing tidal wetlands to a fraction of their current levels while maintaining wetland flushing at current levels. Overall water age in the existing wetlands is reduced from present levels for this alternative. The major potential deleterious effect of this plan is a reduction in flushing in the mid-section of Huntington Harbour where dissolved oxygen resources are limited.

293. The navigable entrance with existing connector to Huntington Harbour maintains the current flushing characteristics in Huntington Harbour, and does not reveal the decrease in flushing observed for the navigable connector channel to Huntington Harbour alternative.

294. The non-navigable entrance channel alternatives do not adversely impact flushing of Huntington Harbour. Overall system residence time in both the existing and proposed full and muted tidal wetlands areas of Bolsa Bay is reduced to a greater degree than for the navigable entrance channel alternatives. Movement of EGG-WFCC runoff into the existing muted tidal wetland region is substantially reduced, although not to quite the same extent as for the navigable entrance channel alternatives. Runoff from EGG-WFCC into the proposed non-navigable entrance channel concept muted tidal wetlands is somewhat less than into the existing muted tidal wetlands, but these inflows may be high enough to have a deleterious affect on the wetlands. Any new entrance (navigable or non-navigable) should be maintained to enhance water quality aspects of both the proposed full and muted tidal wetland regions.

Summary Conclusions

295. The development of either a new navigable (Preferred Alternative) or non-navigable (Secondary Alternative) entrance channel system to Bolsa Bay with associated marinas, full tidal, and muted tidal wetland enhancement, is feasible from engineering, hydrodynamic, and water quality standpoints investigated by this study. The non-navigable (Secondary Alternative) entrance channel system does not adversely impact flushing of Huntington Harbour, and the overall residence times in both the full and muted tidal wetland areas of Bolsa Bay are reduced to a greater degree than for the navigable (Preferred Alternative) entrance channel concept. Since the non-navigable entrance channel could be reopened immediately following closure by a storm, other related environmental elements such as water age may not be adversely impacted. Any potential for scour resulting from high velocities near bridges or in Outer Bolsa Bay could be prevented by channel stabilization measures provided as part of project construction. The Bolsa Bay complex will provide for multiple public and private uses with an emphasis on wildlife habitat enhancement, public recreation, coastal access, and water dependent residential development.

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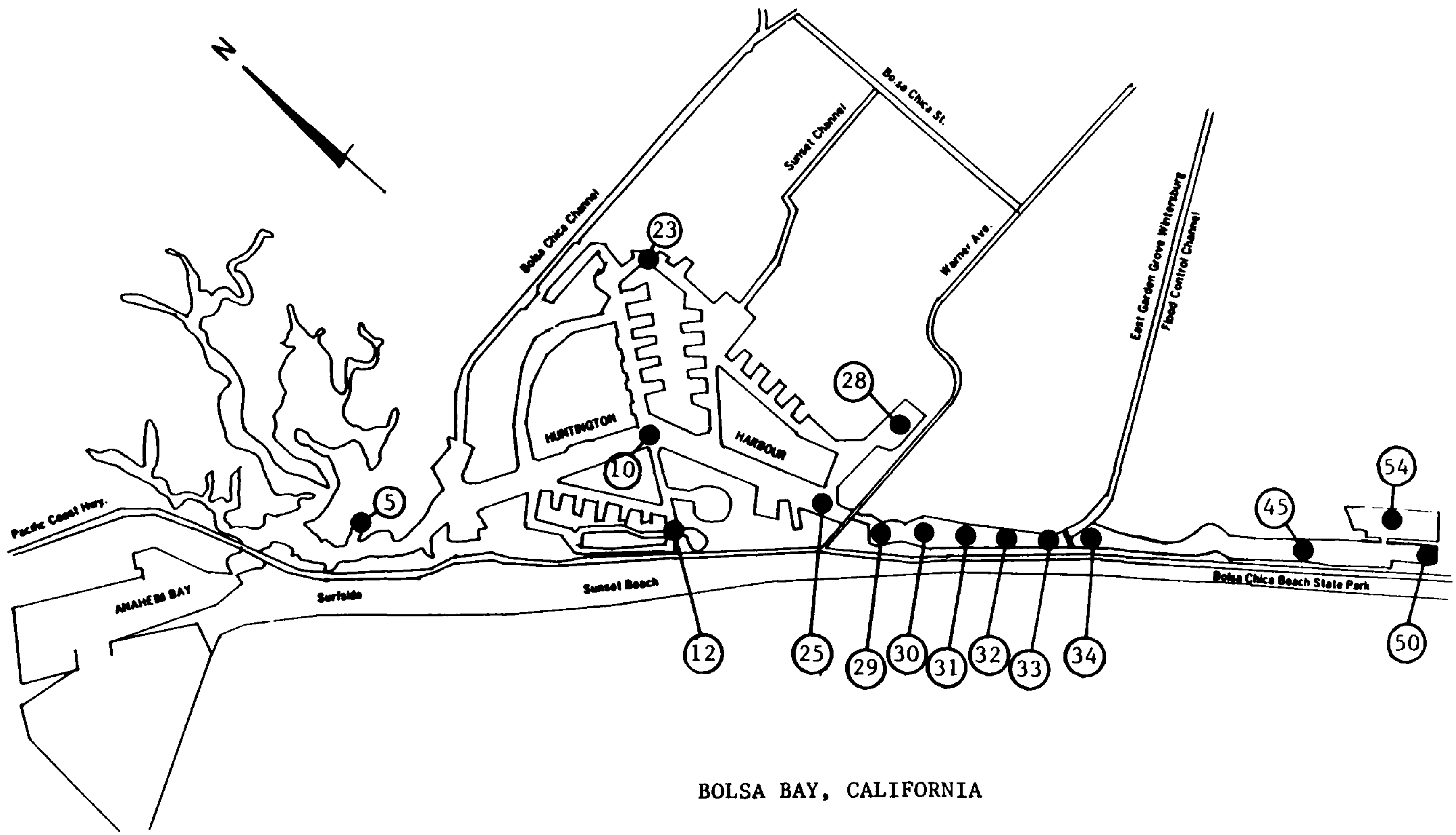
APPENDIX A:

EXISTING CONDITION

WATER SURFACE ELEVATIONS



BOLSA BAY, CALIFORNIA

Location of nodes for displaying
water surface elevations under existing conditions

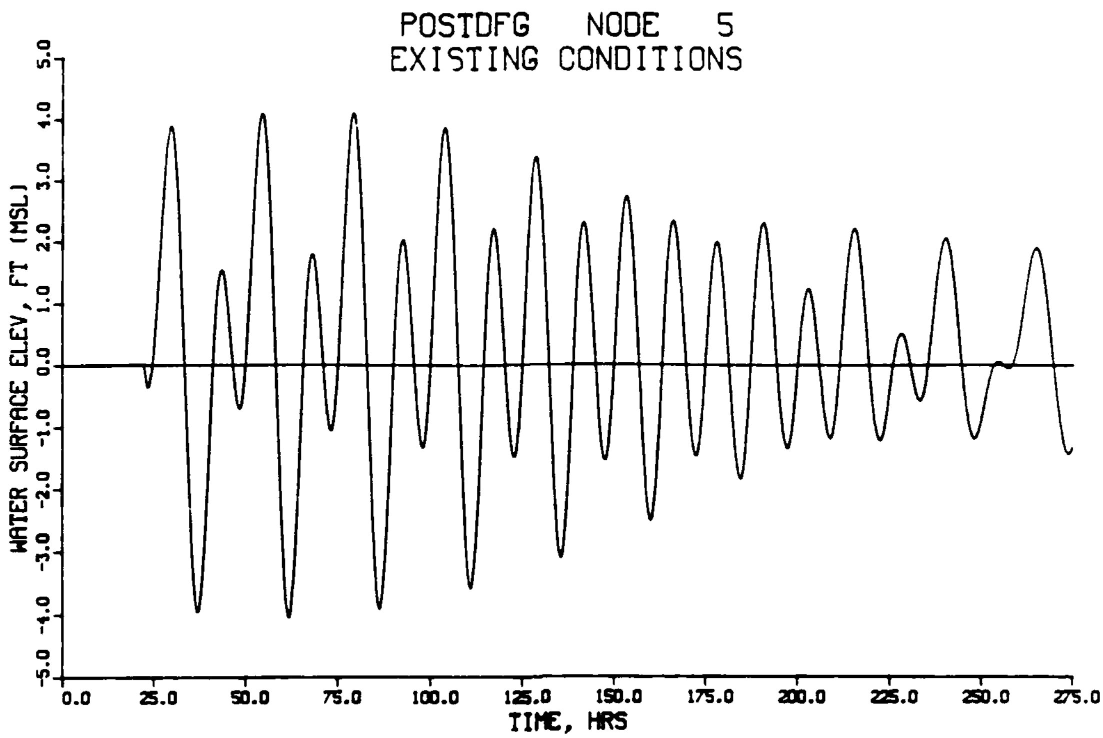
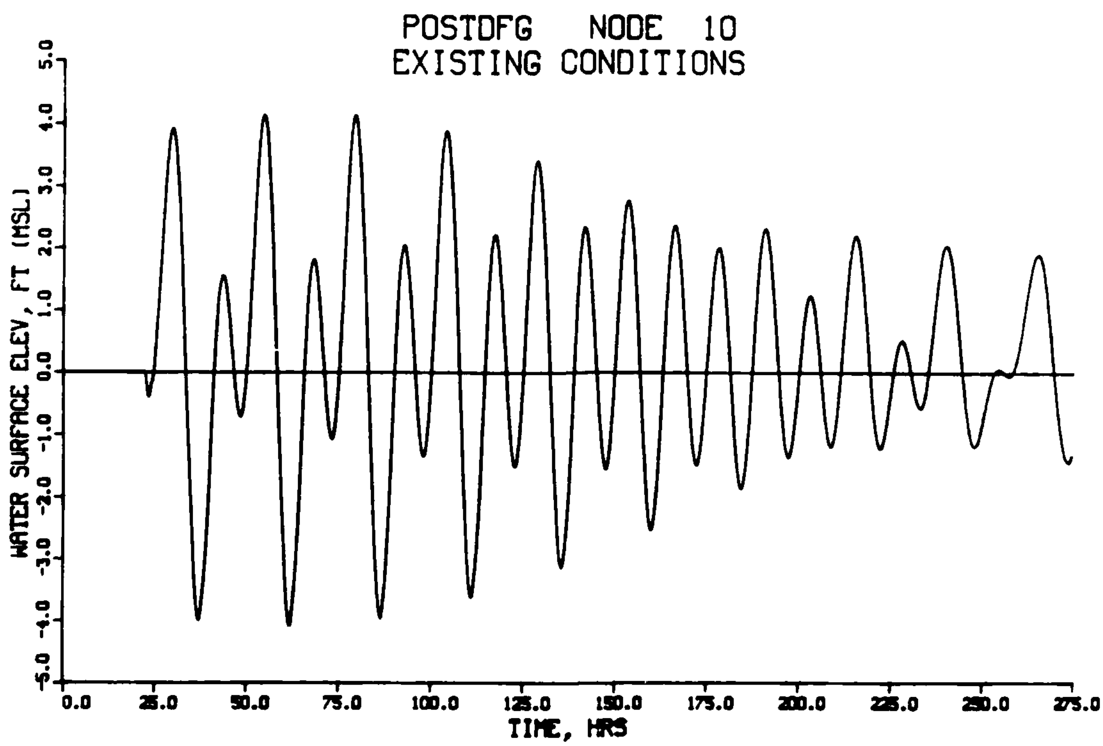


Figure A1. Tidal elevations in Huntington Harbour



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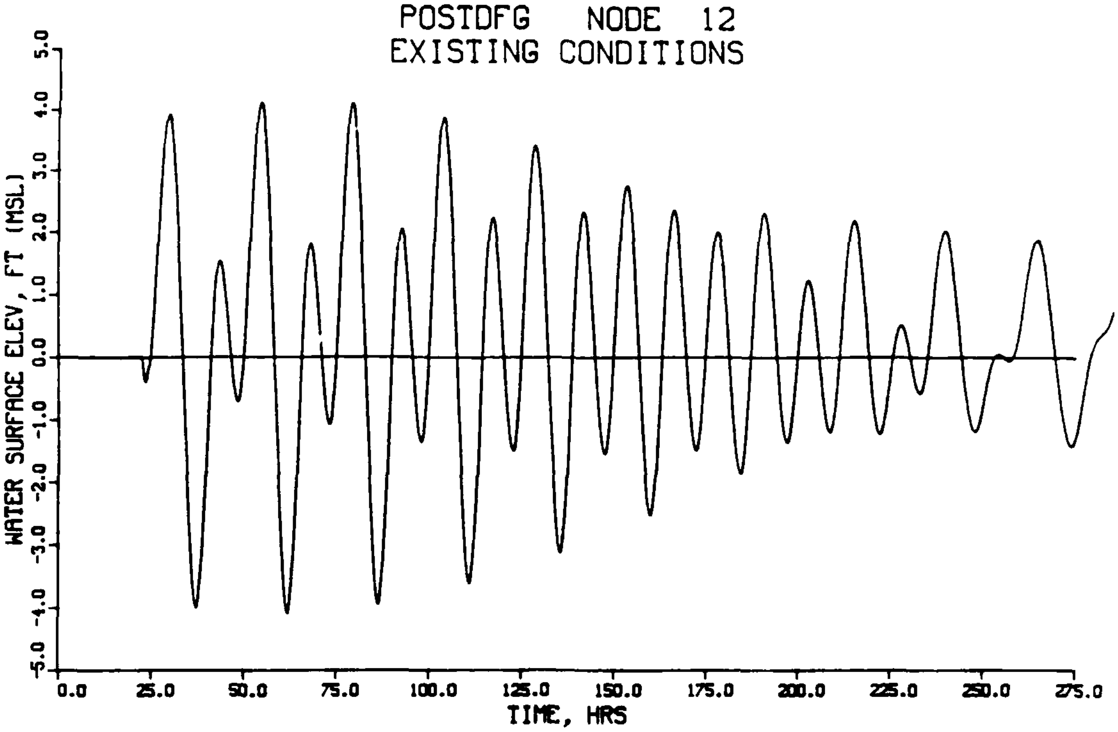

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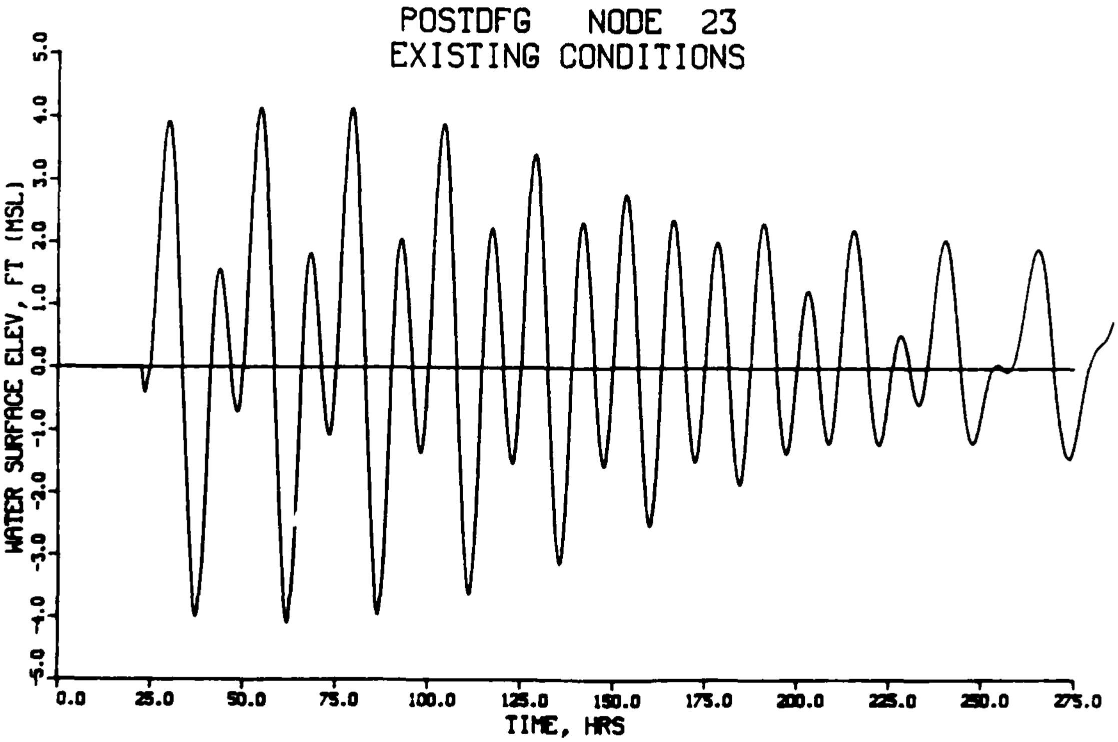

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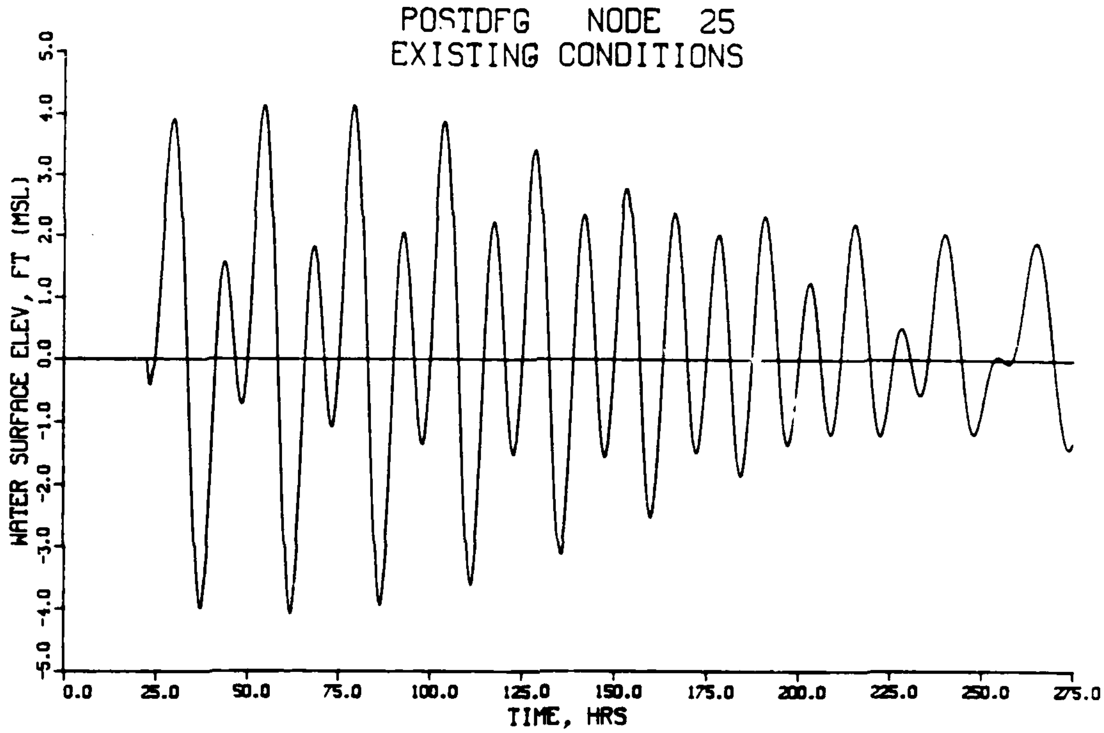

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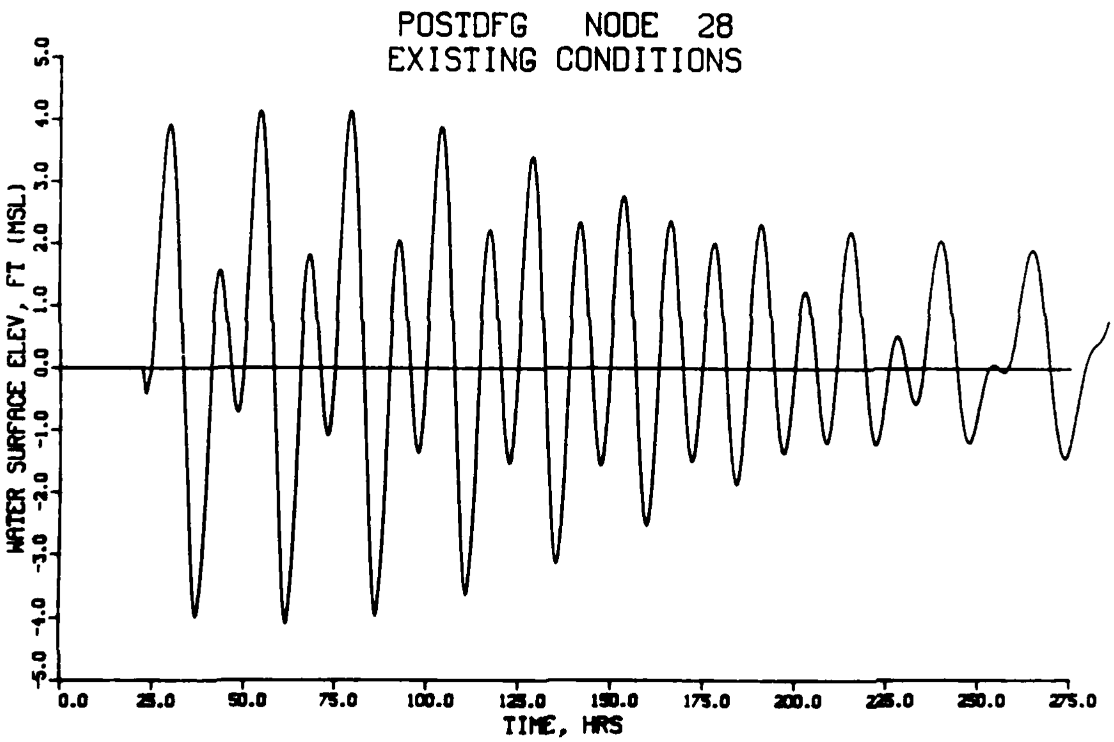

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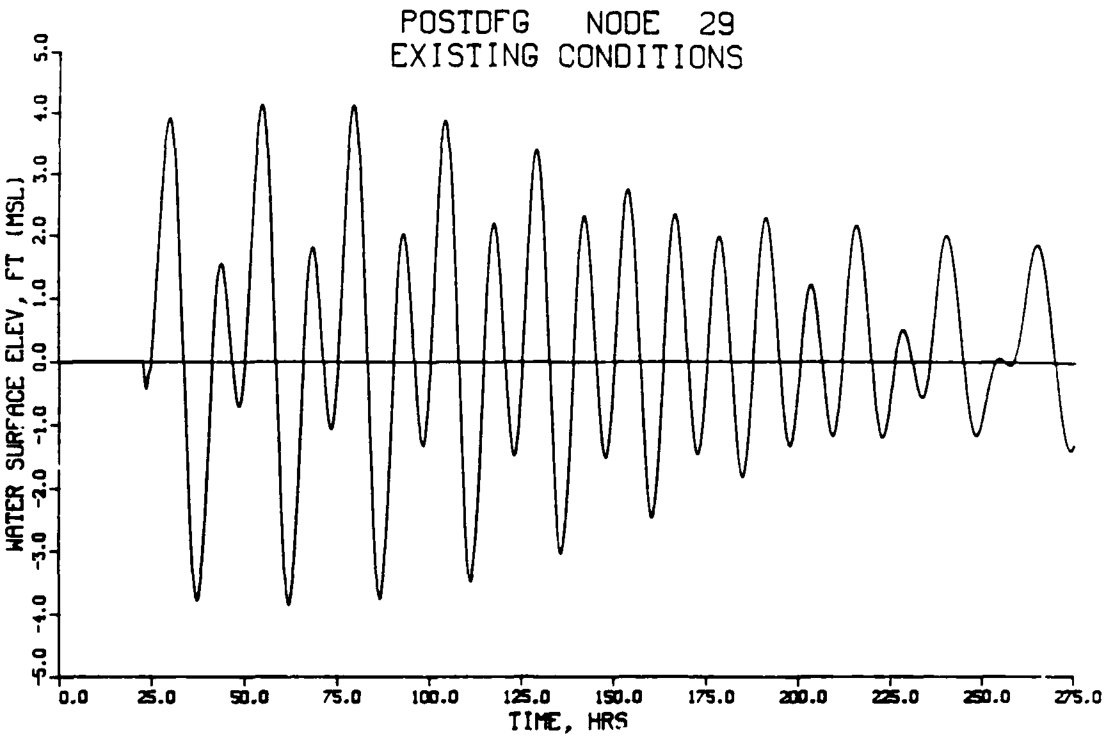

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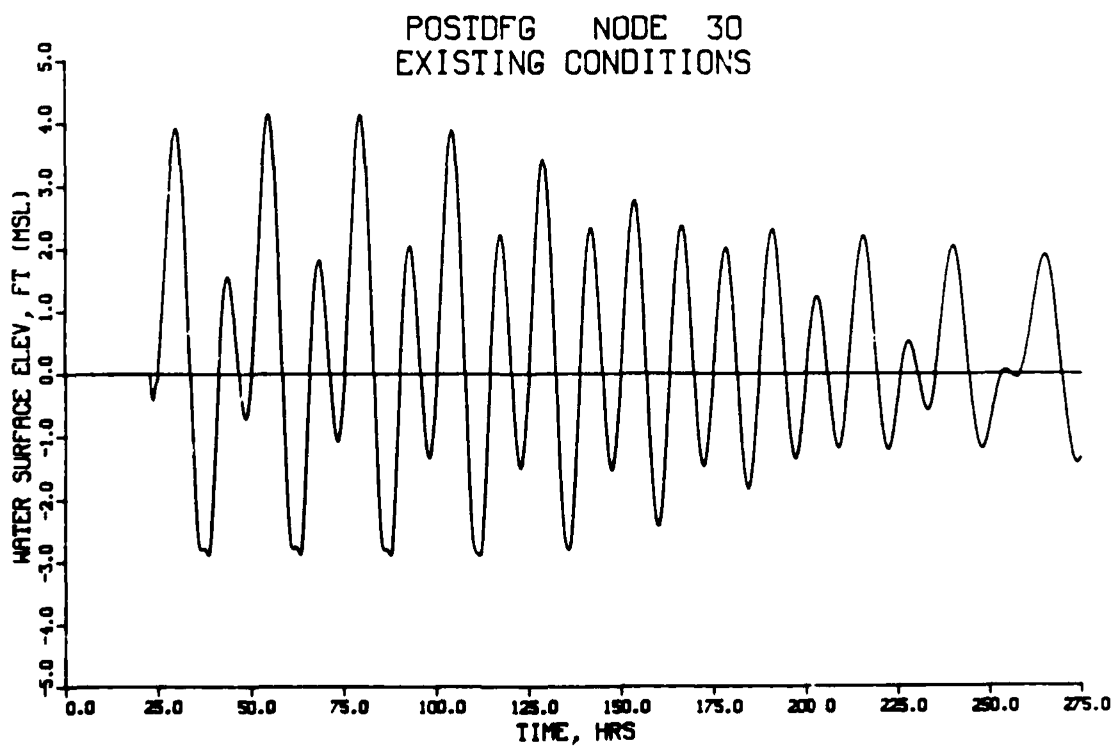

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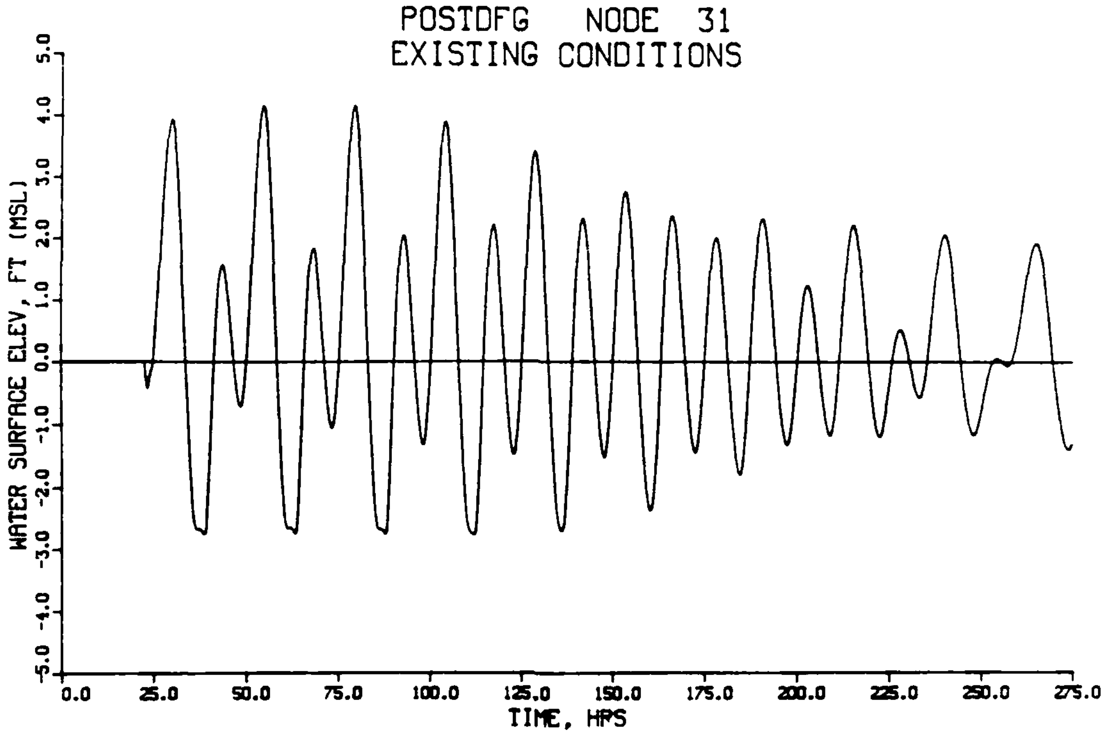
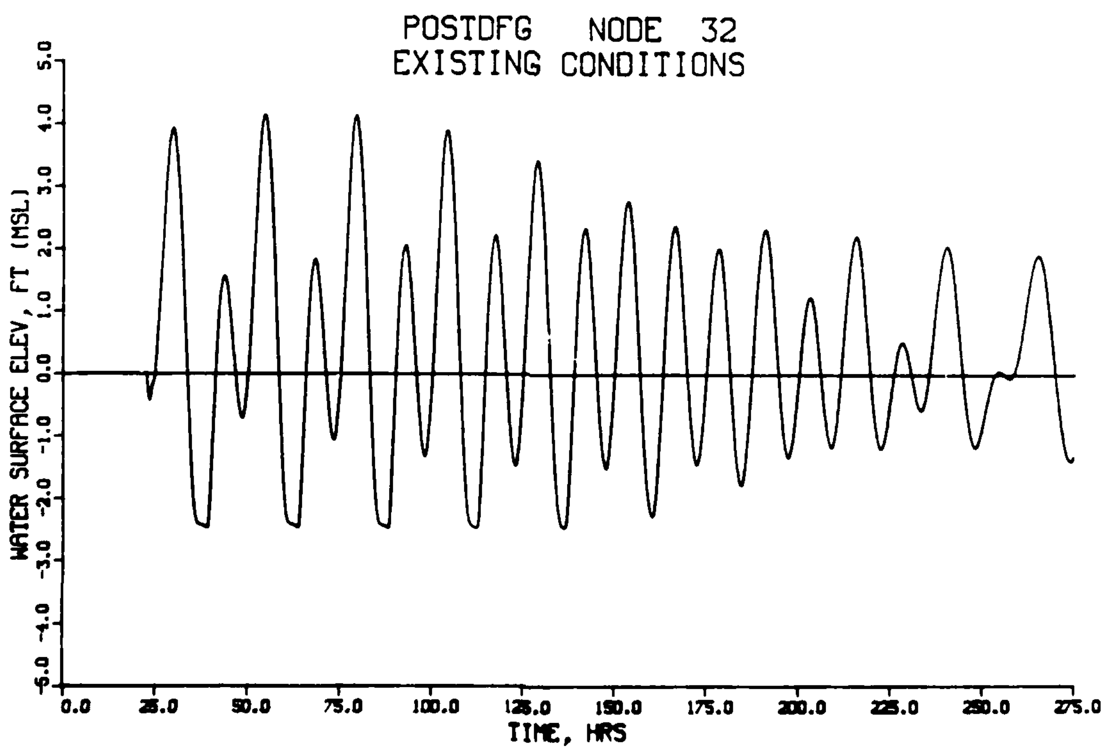


Figure A9. Tidal elevations in Outer Bolsa Bay



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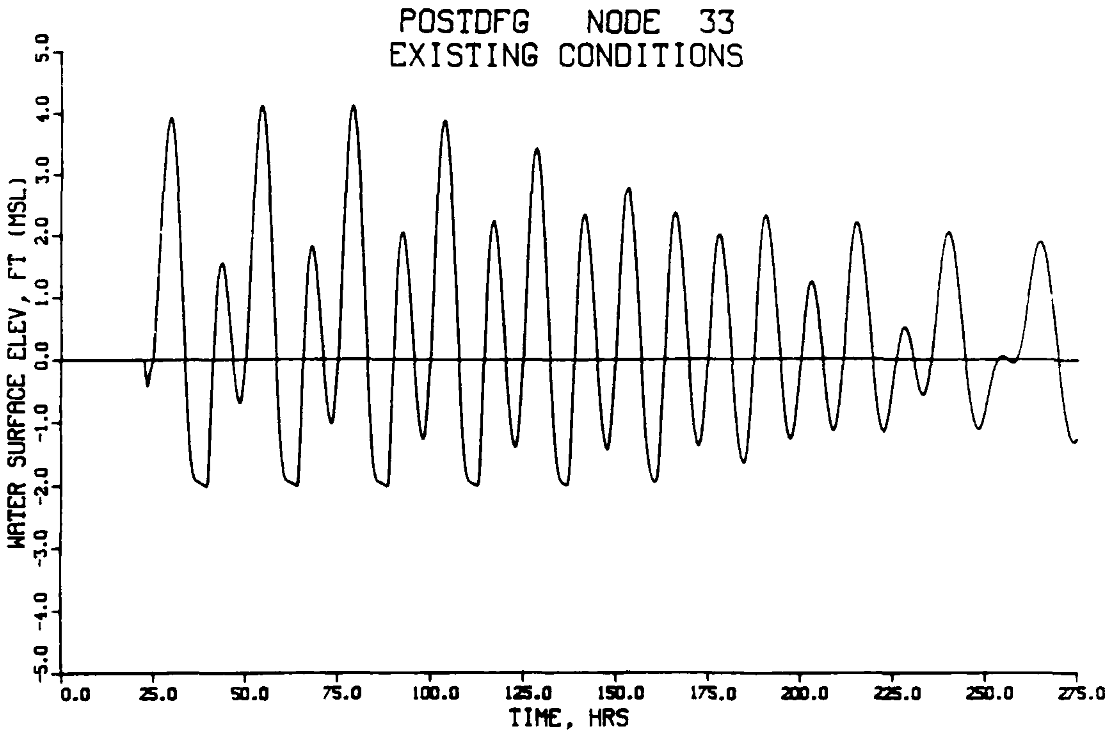

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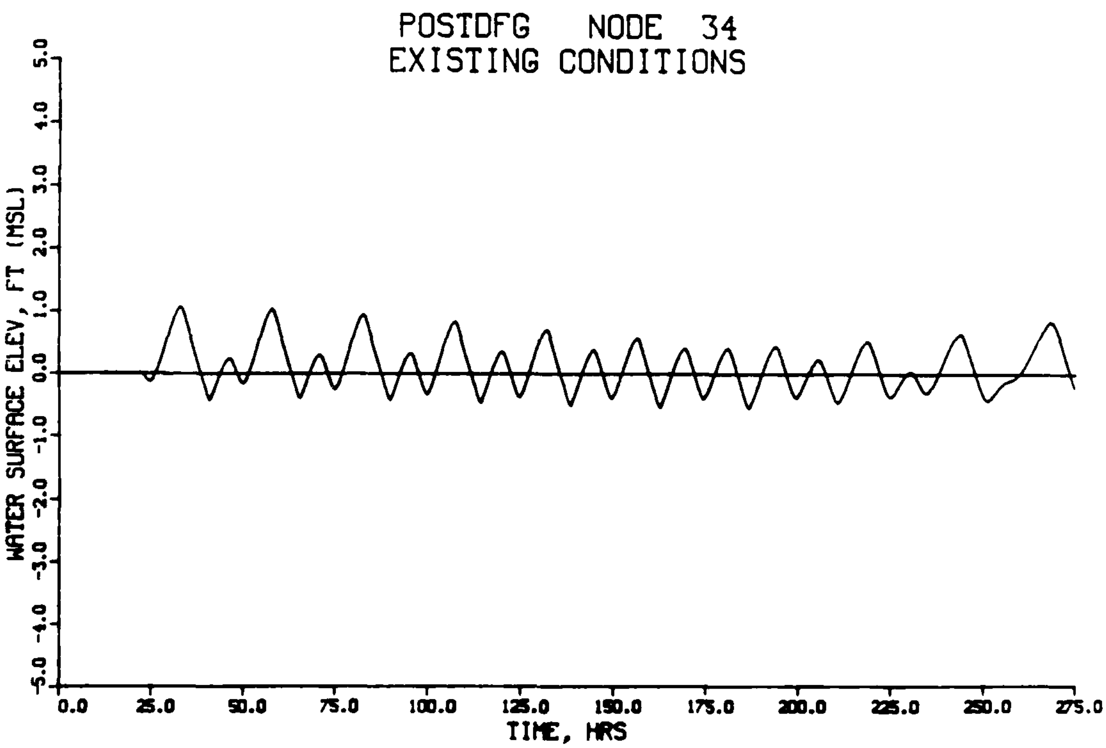
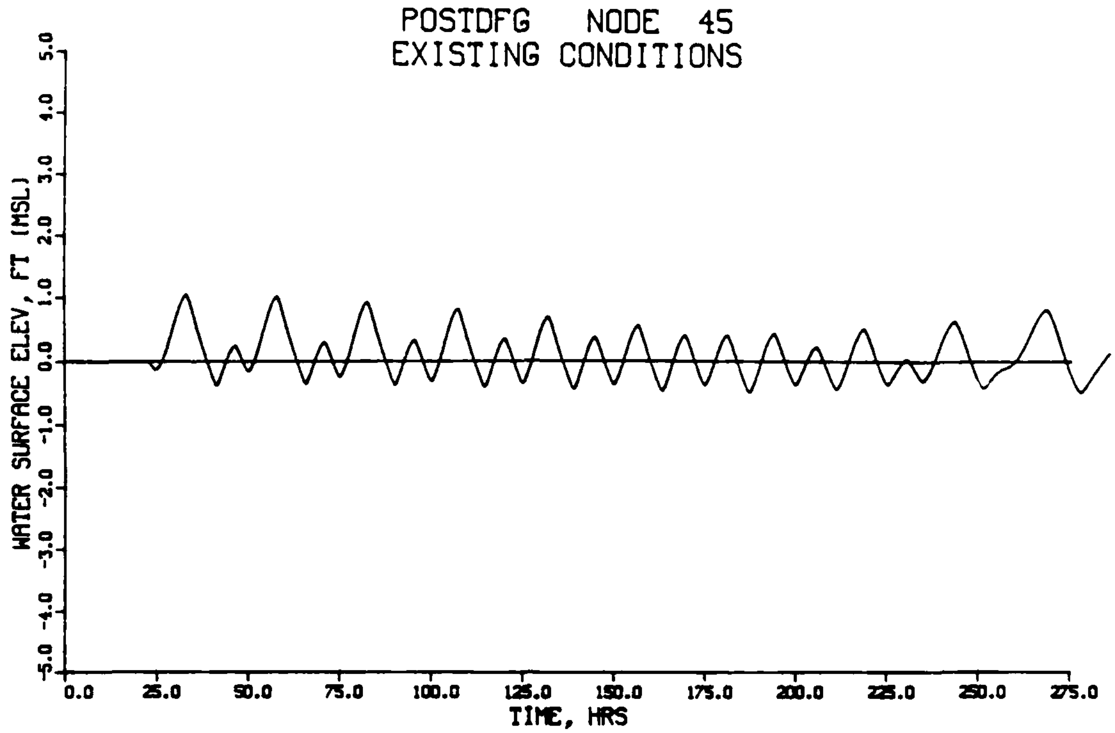


Figure A12. Tidal elevations in Inner Bolsa Bay



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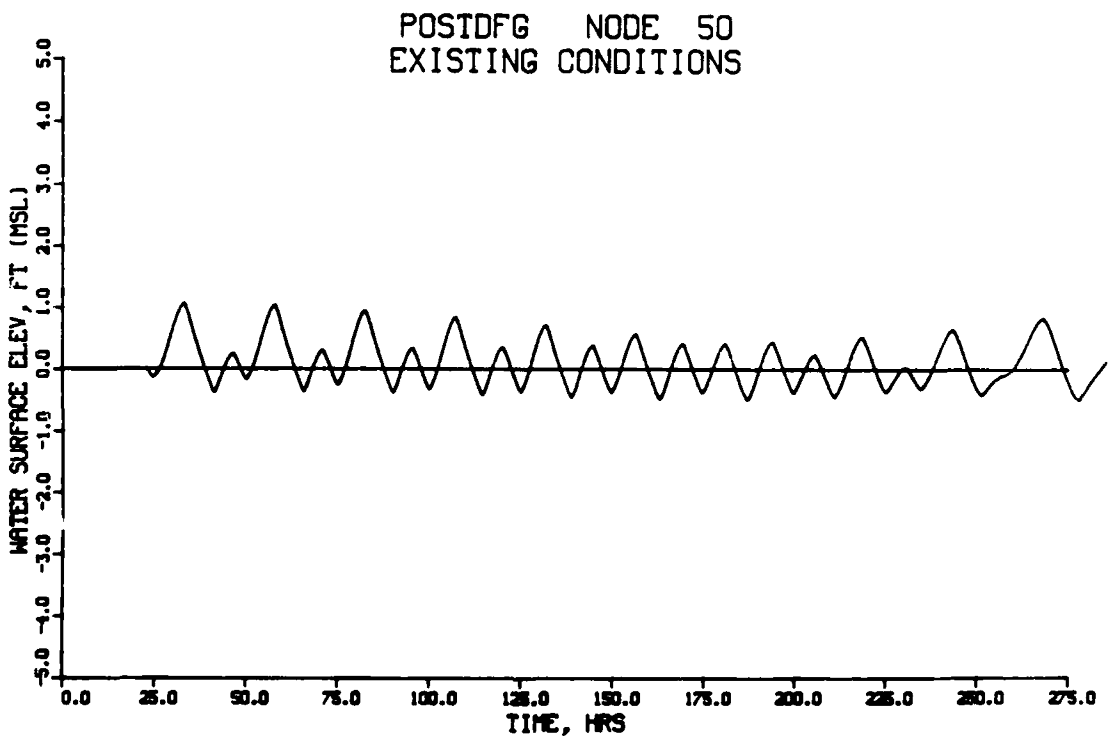

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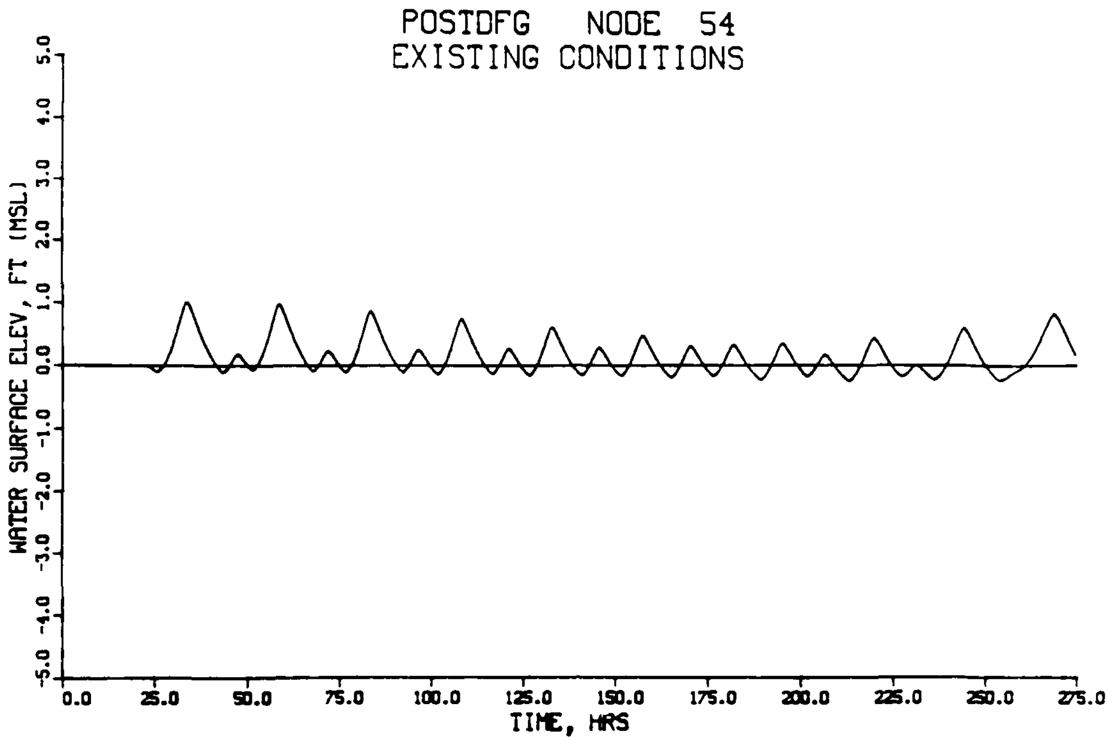
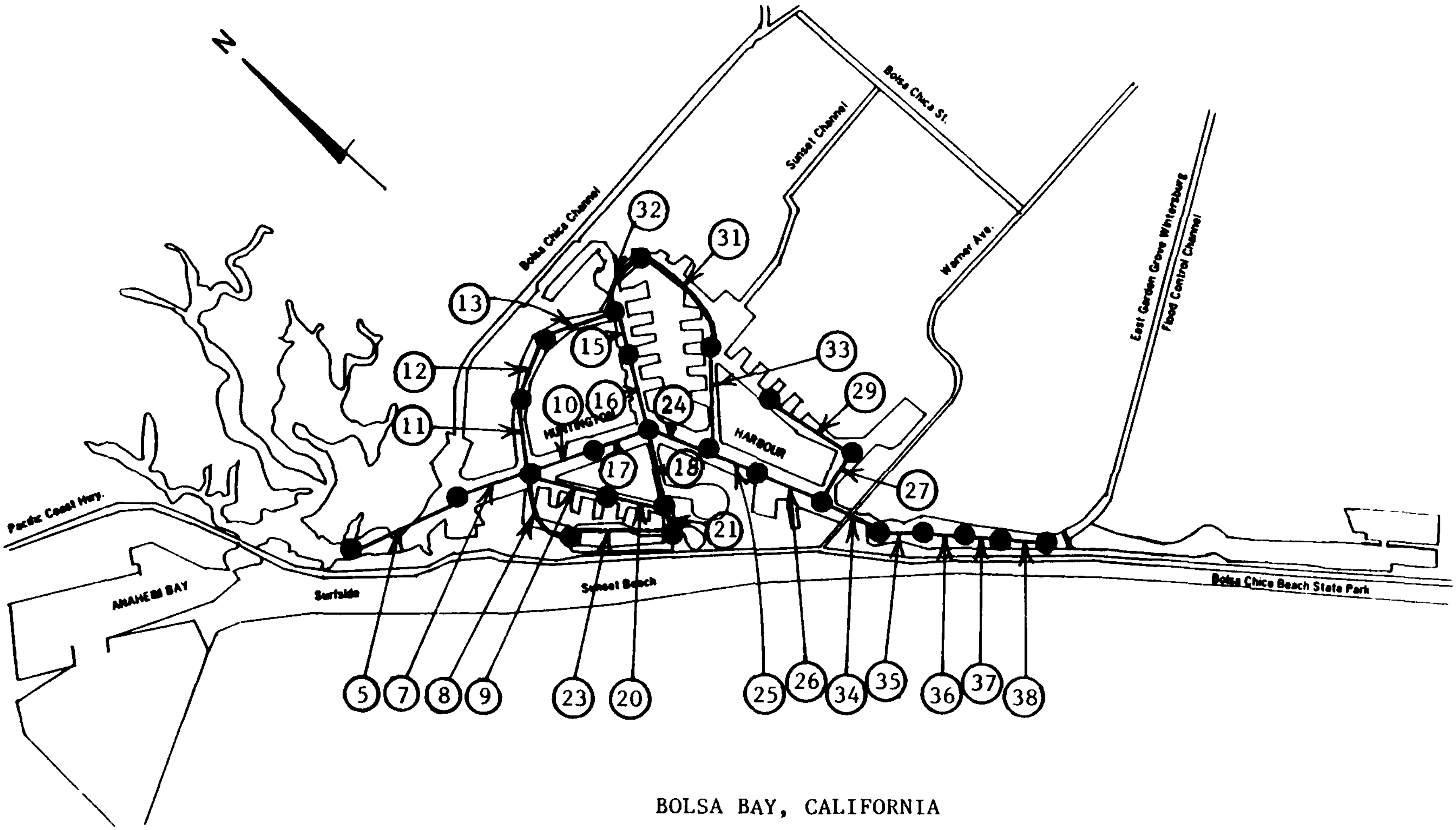


Figure A15. Tidal elevations in DFG muted tidal cell

APPENDIX B:

EXISTING CONDITION

AVERAGE CHANNEL VELOCITIES



BOLSA BAY, CALIFORNIA

Location of links for displaying
average channel velocities under existing conditions

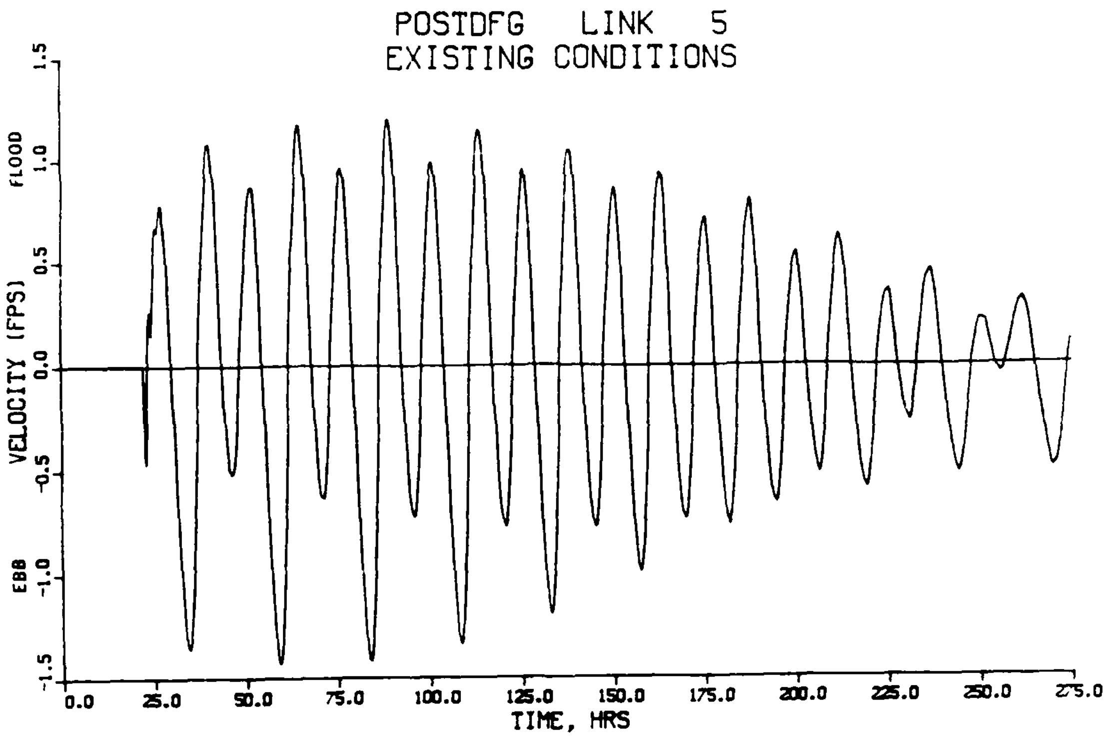
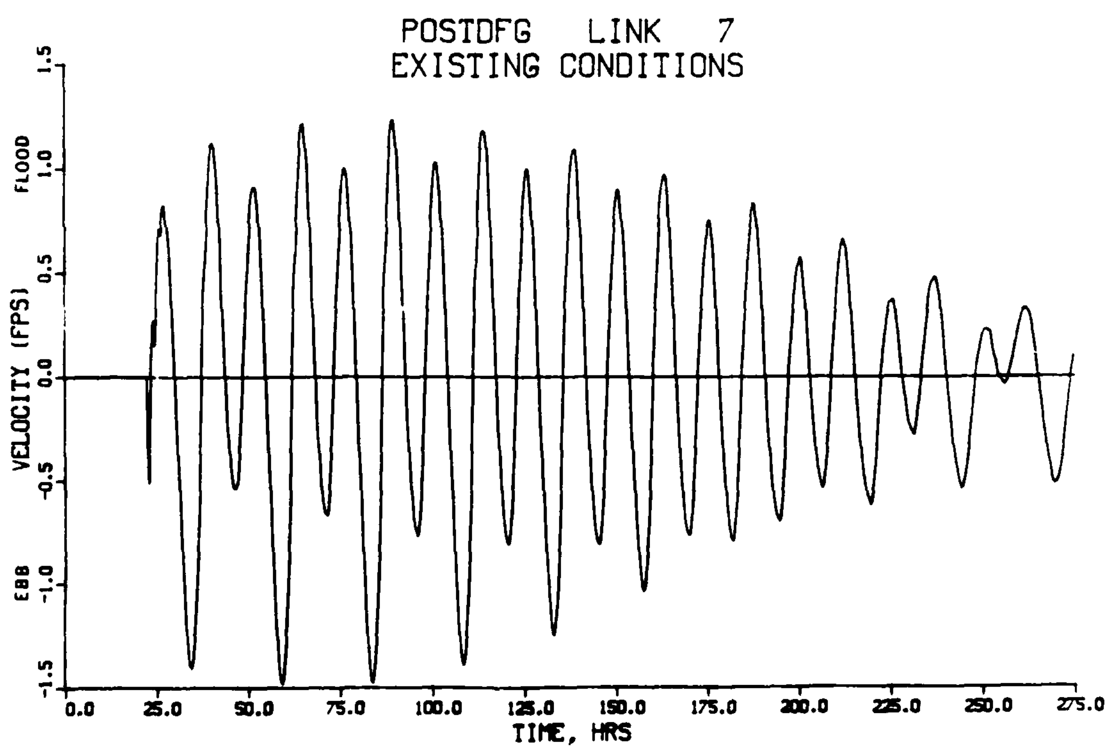


Figure B1. Average channel velocities in Huntington Harbour



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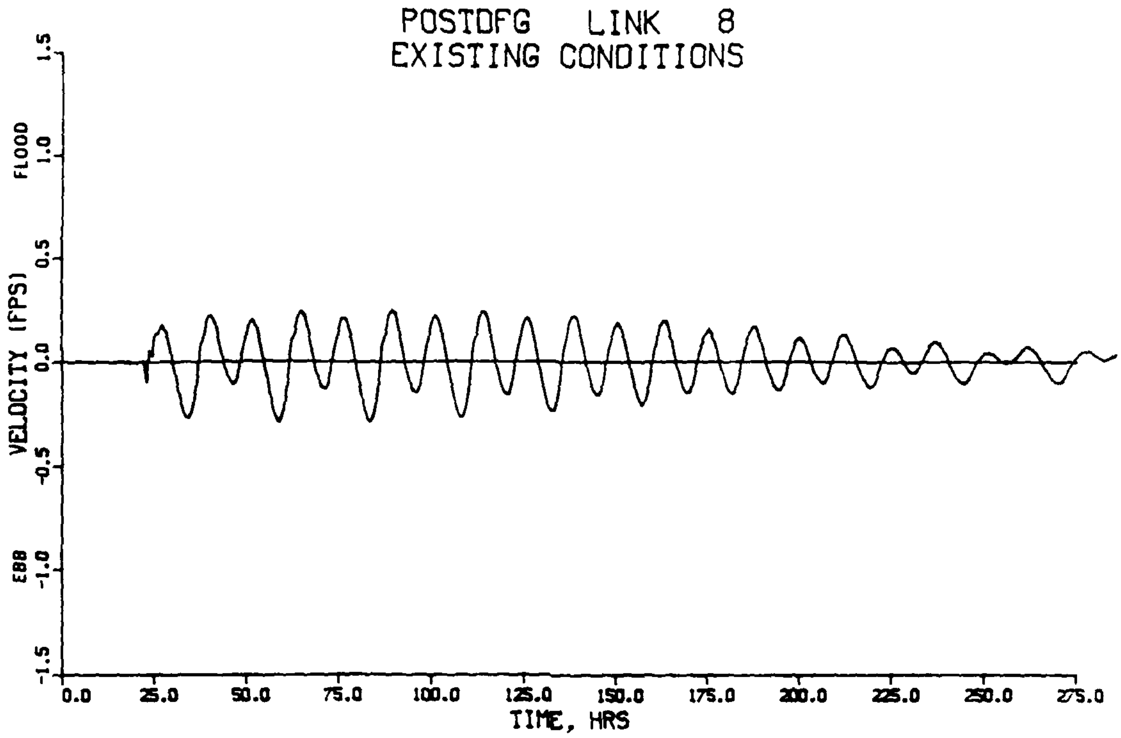

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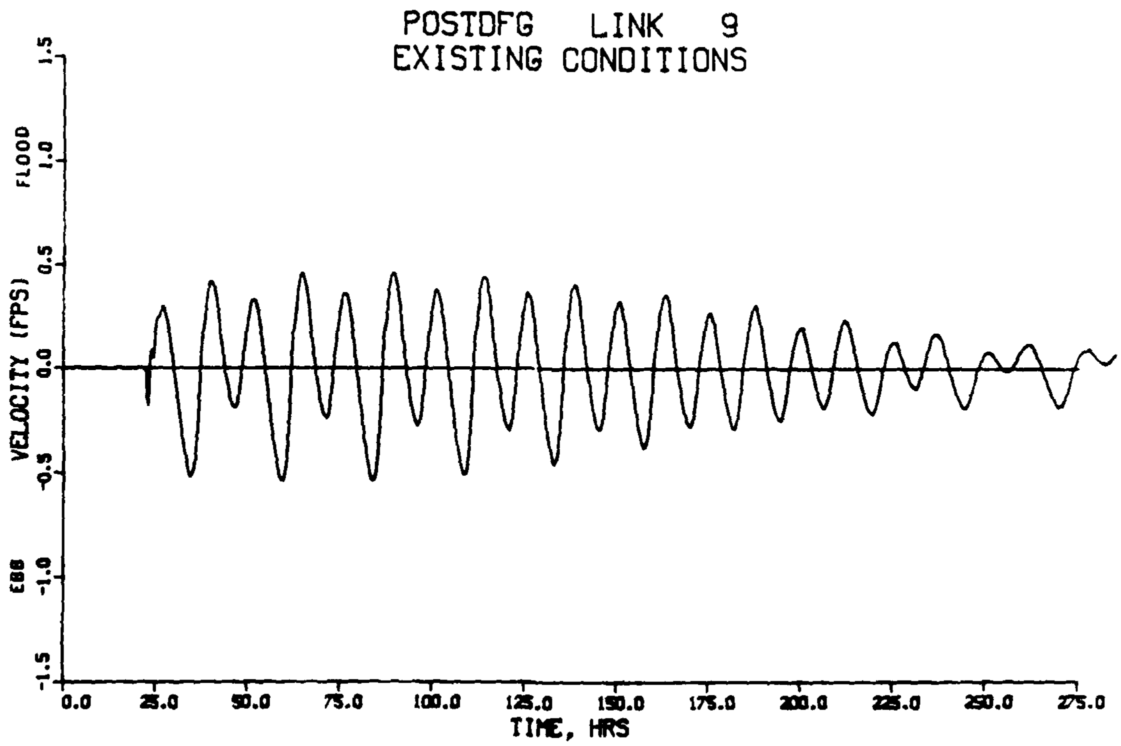

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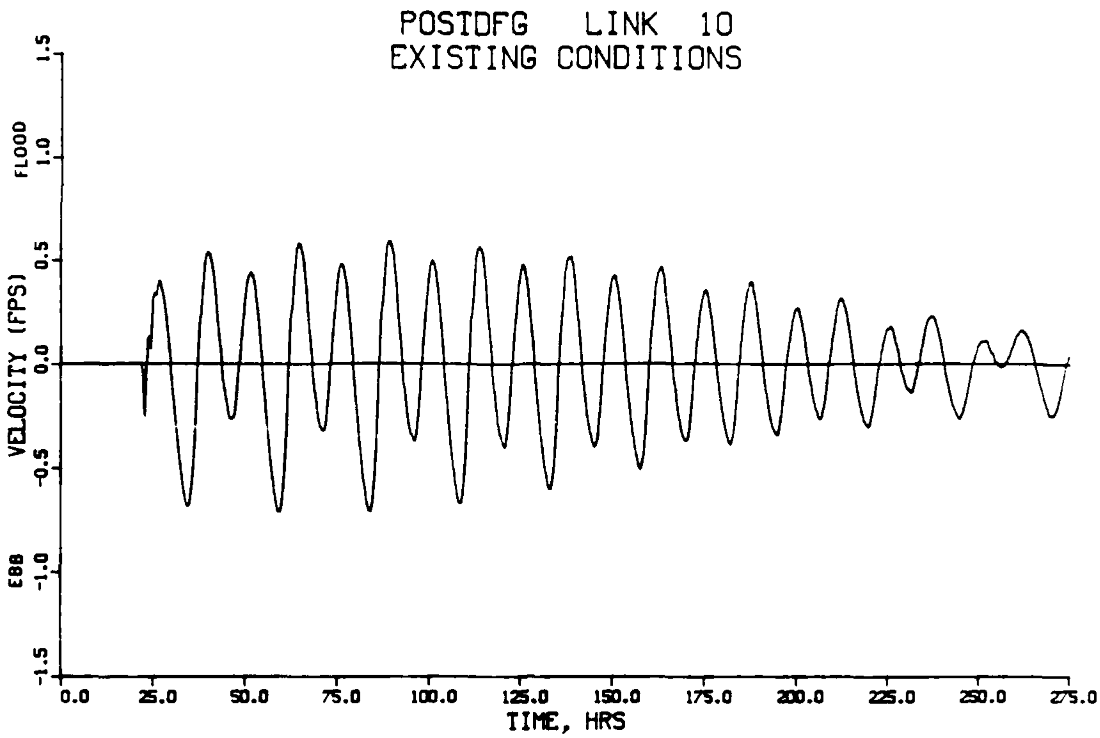

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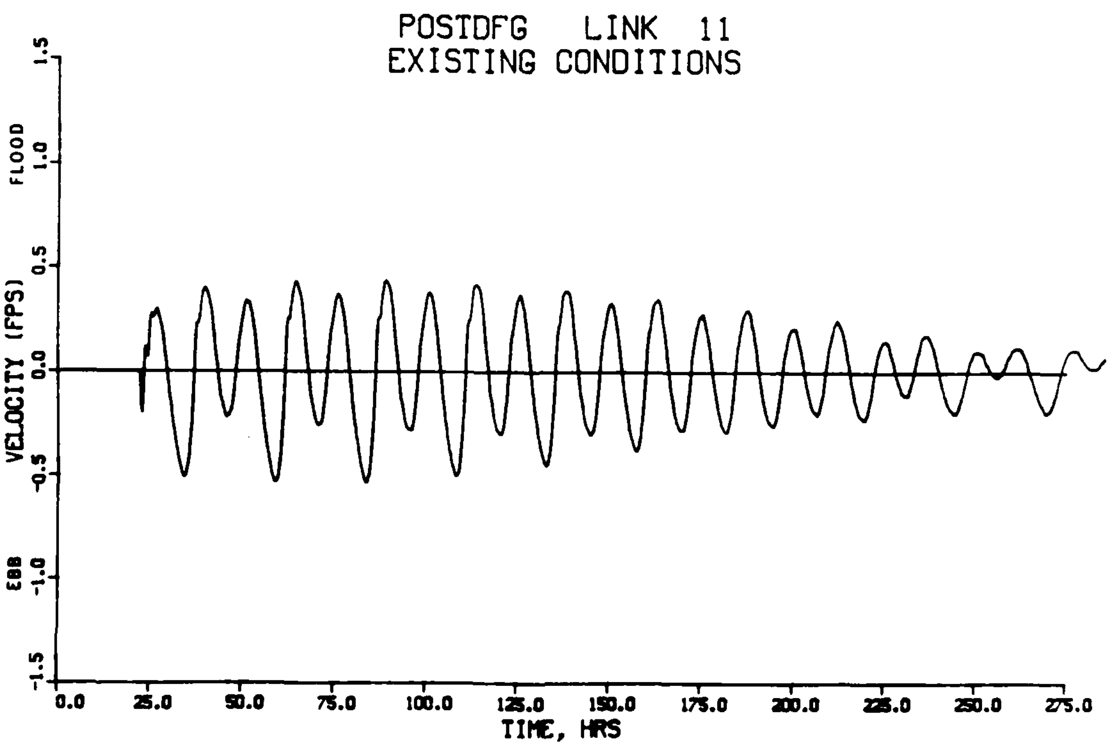

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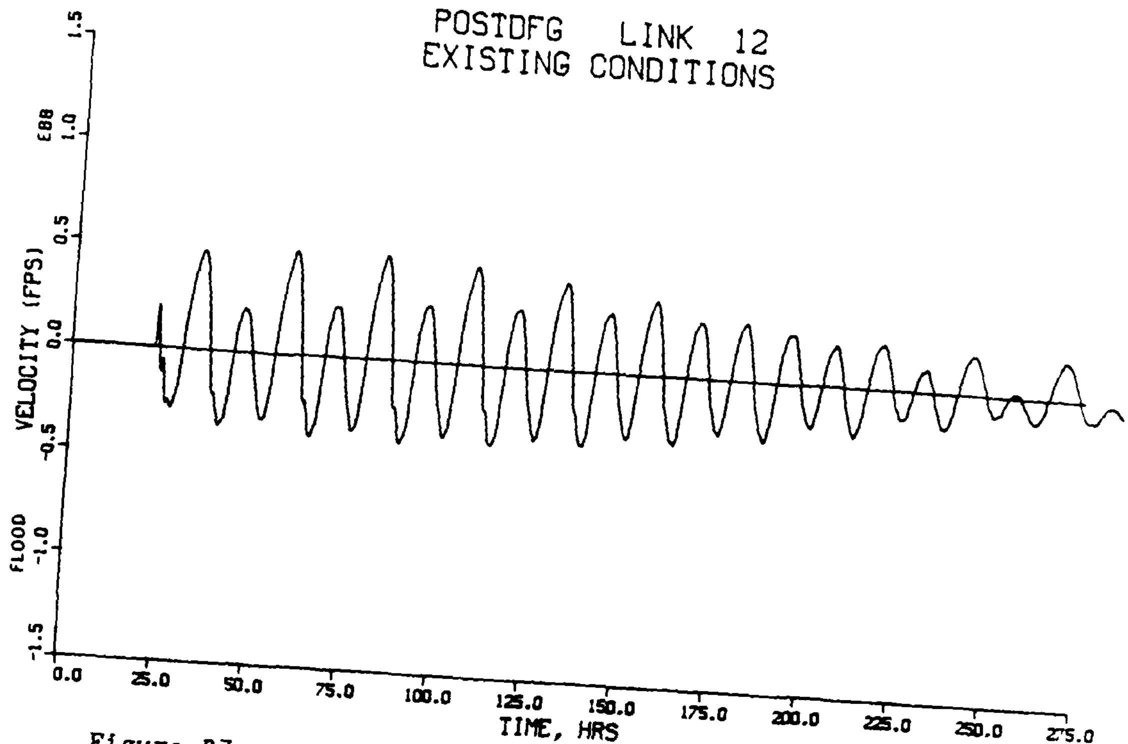

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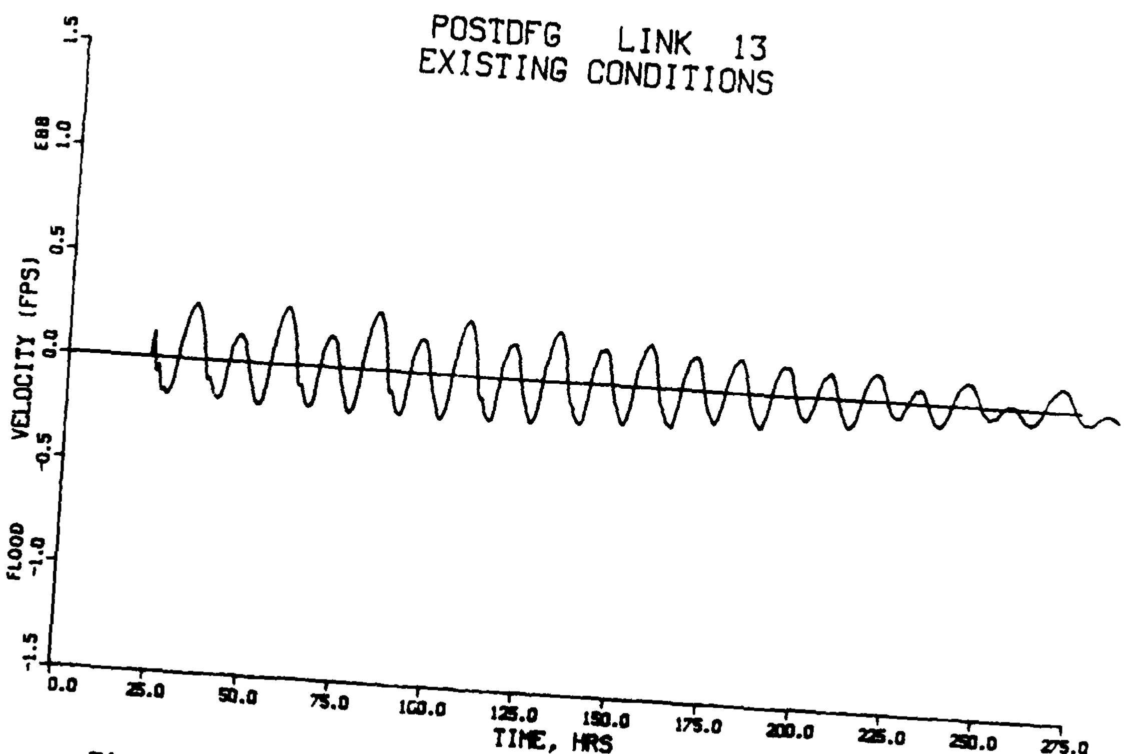

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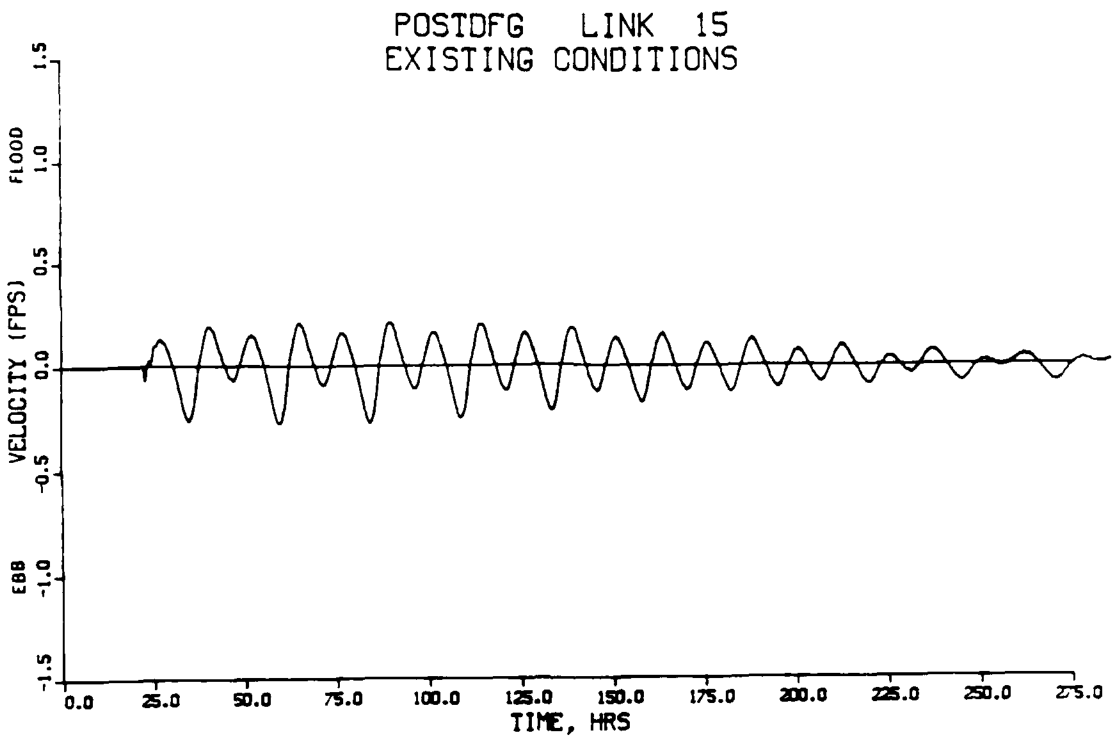

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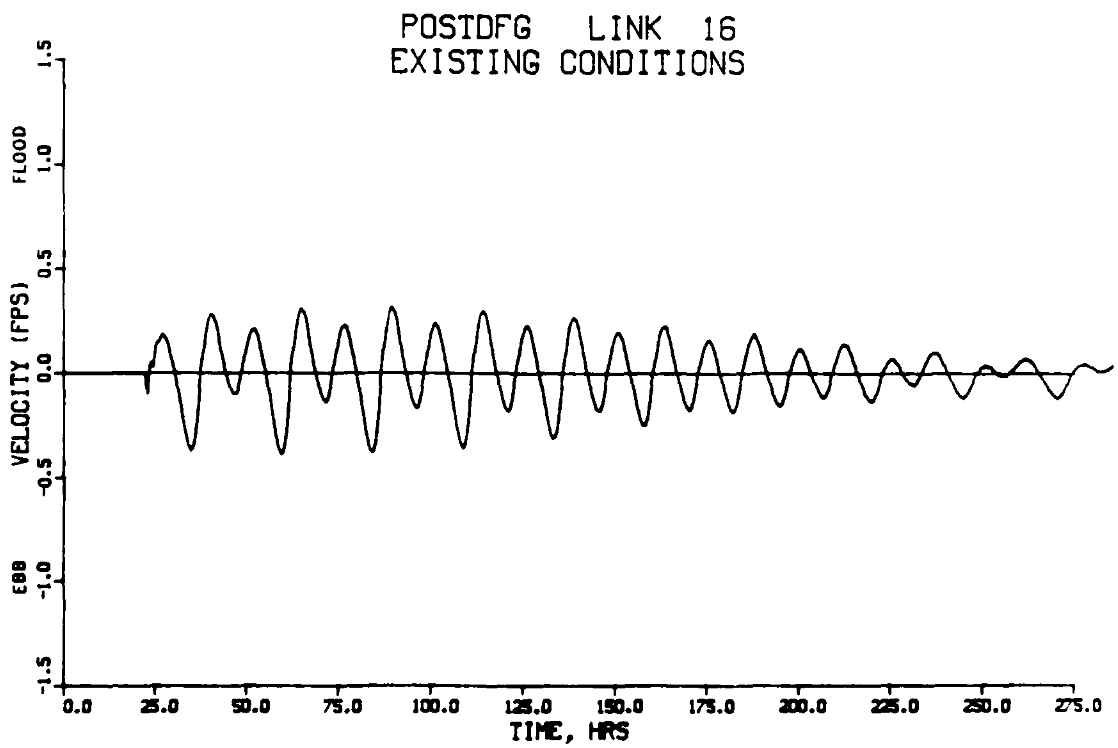

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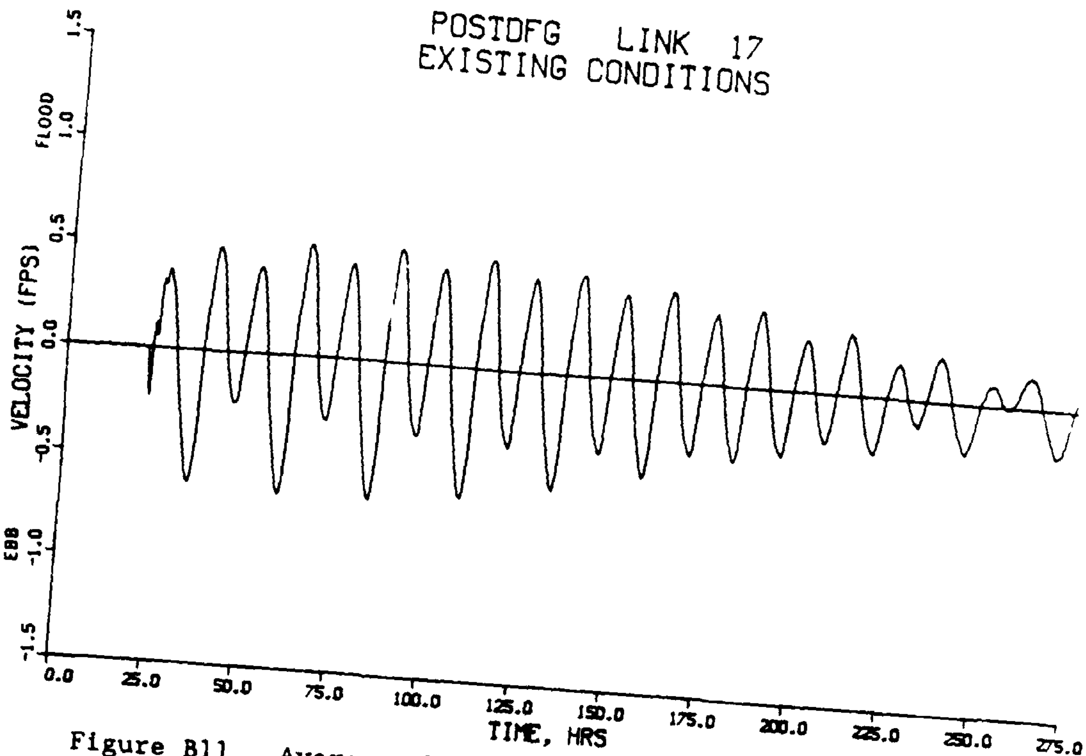

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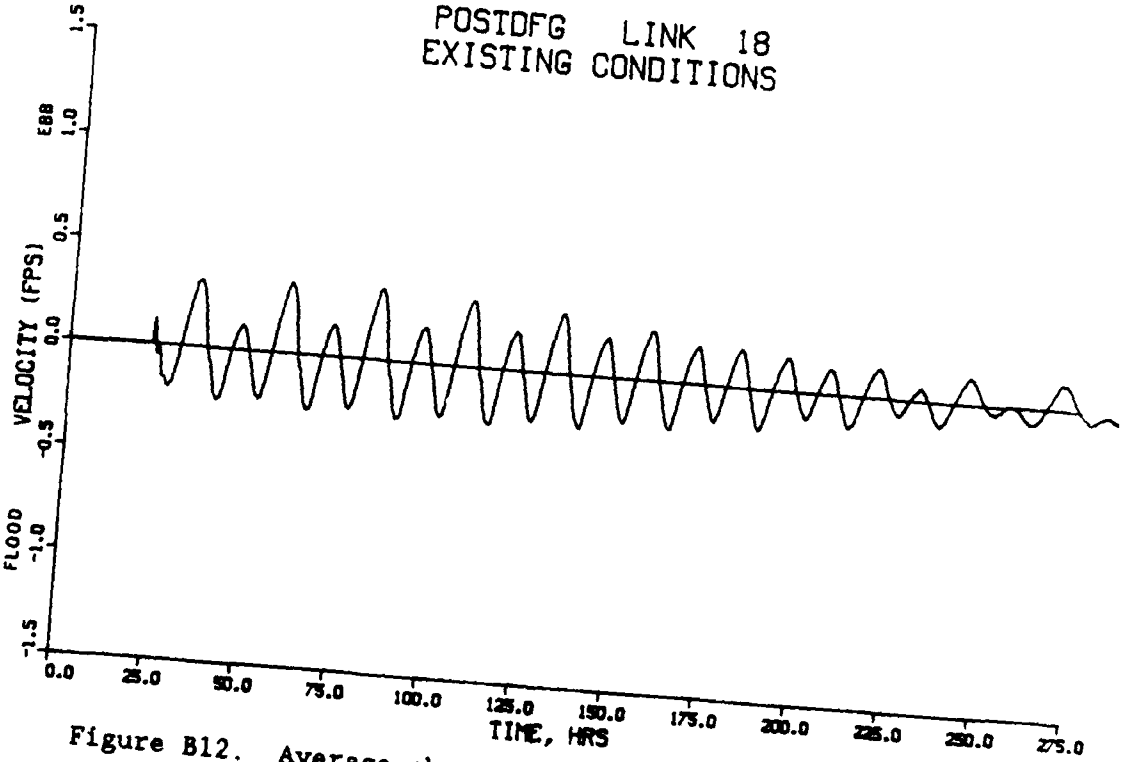

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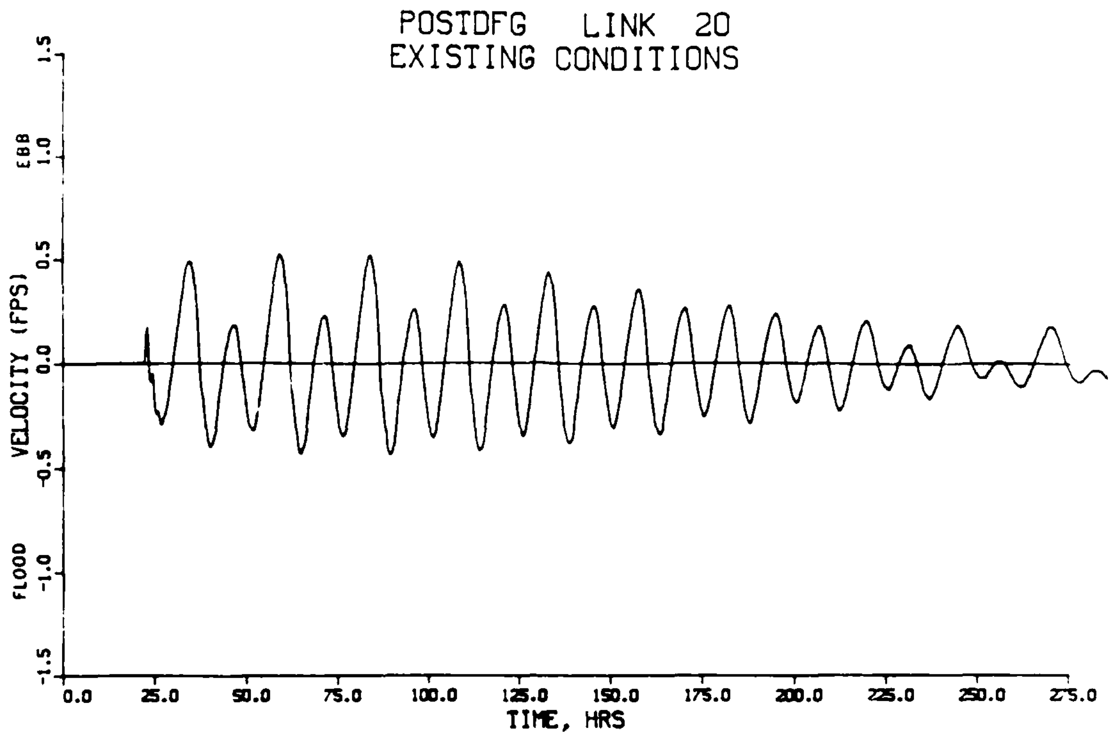

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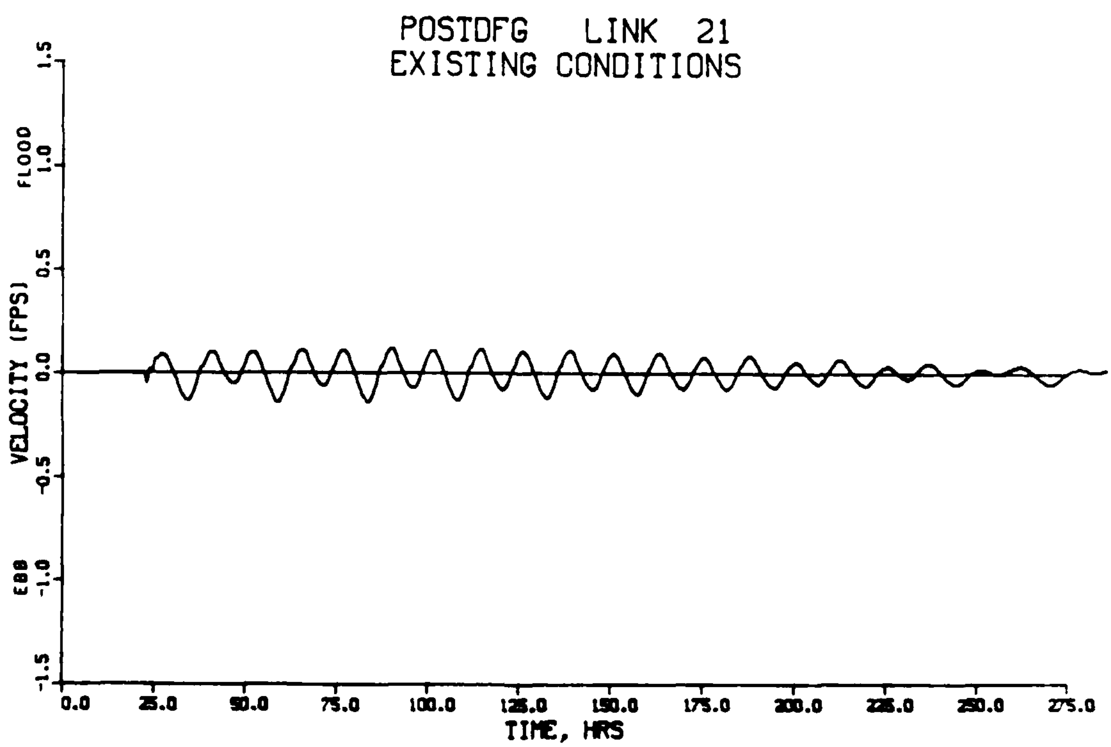

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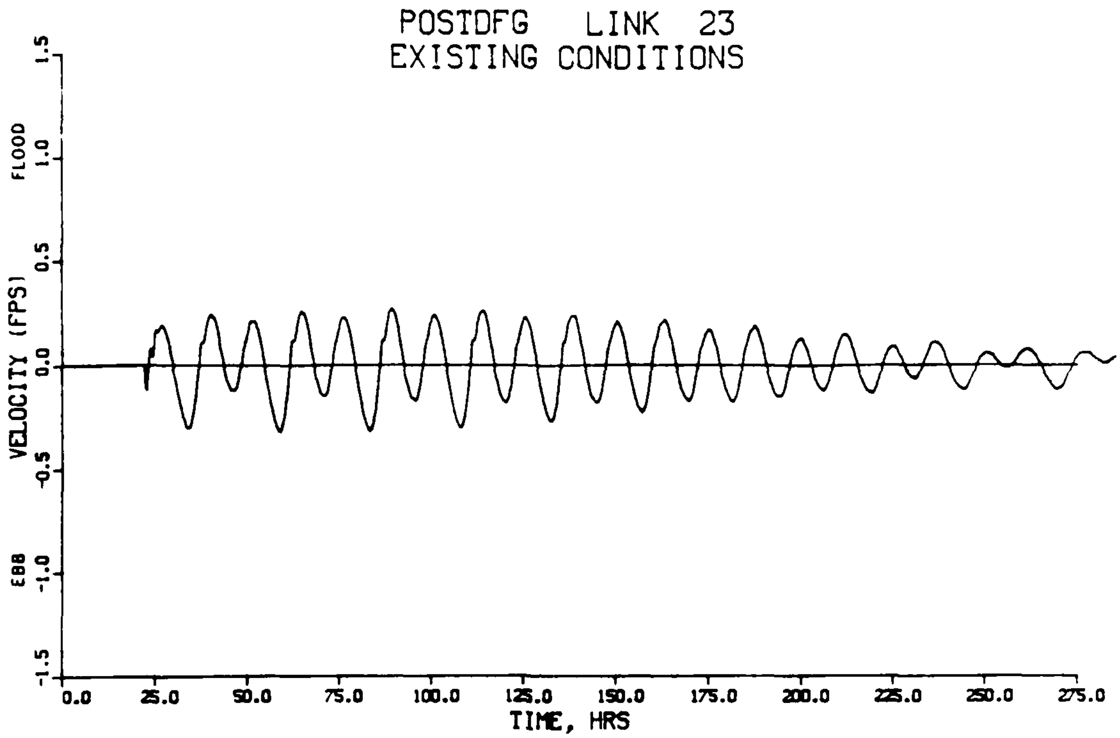

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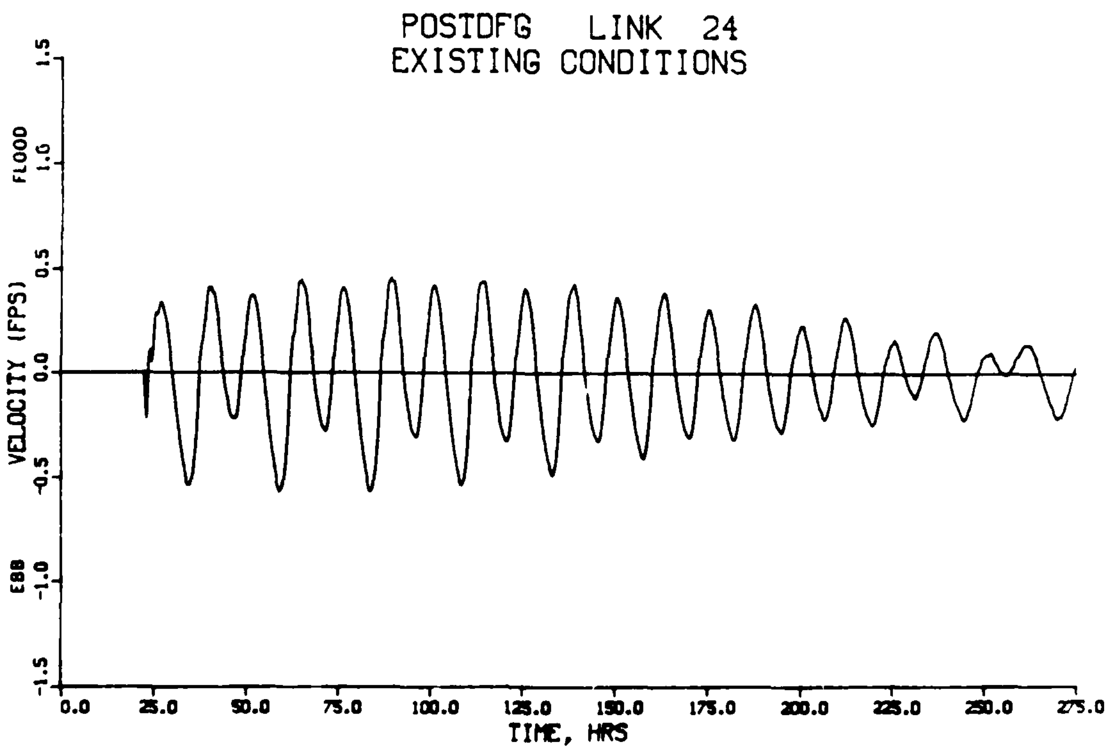

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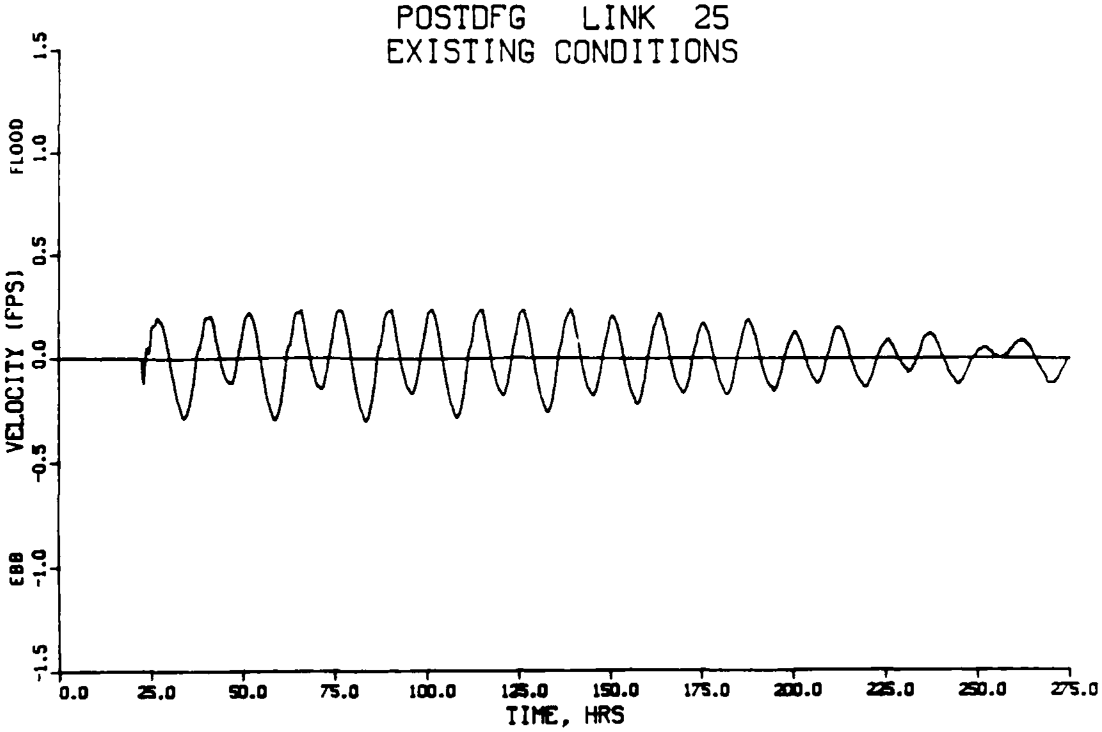

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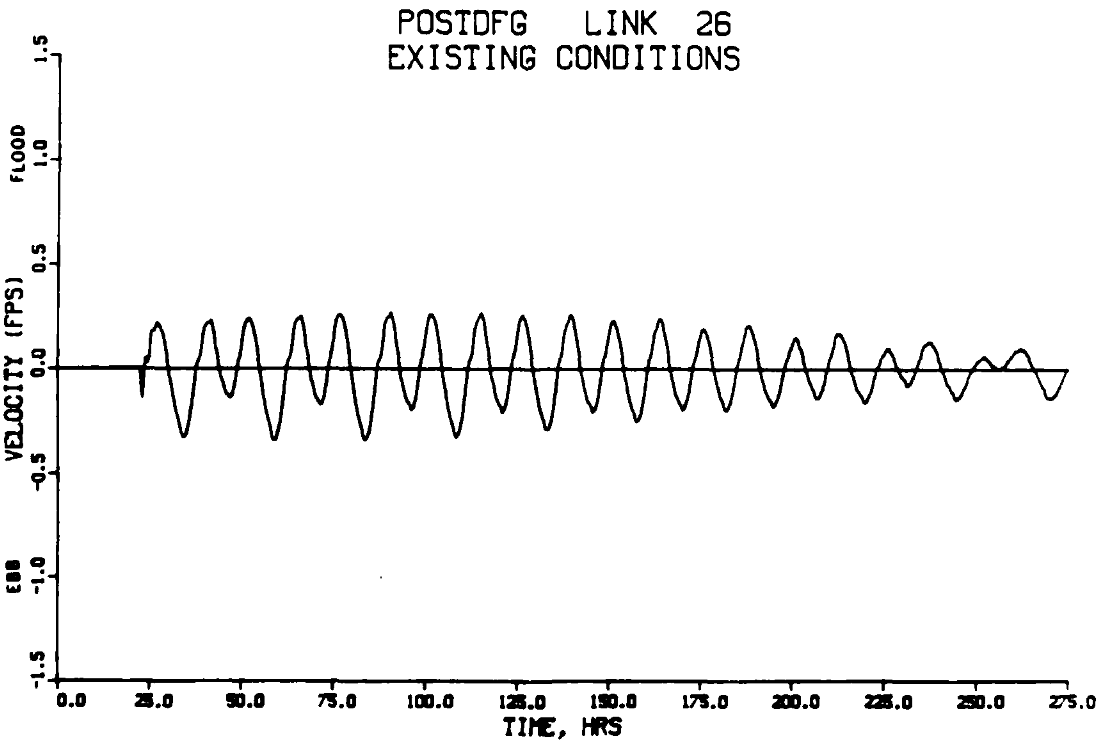

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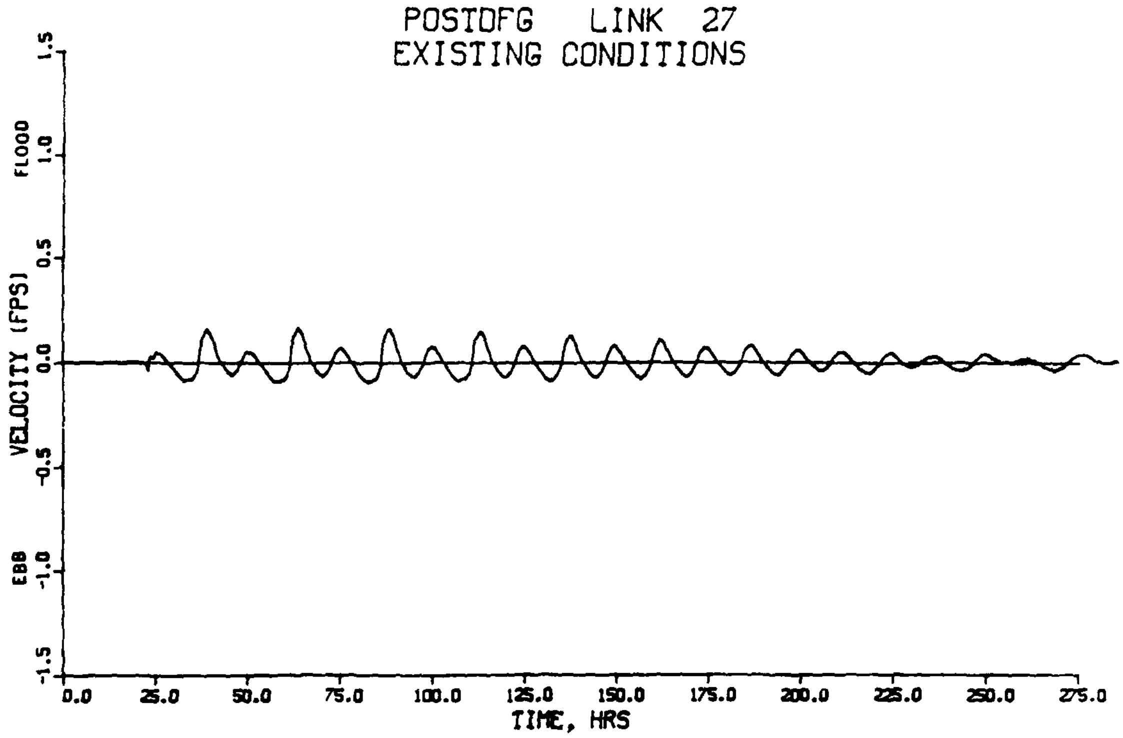

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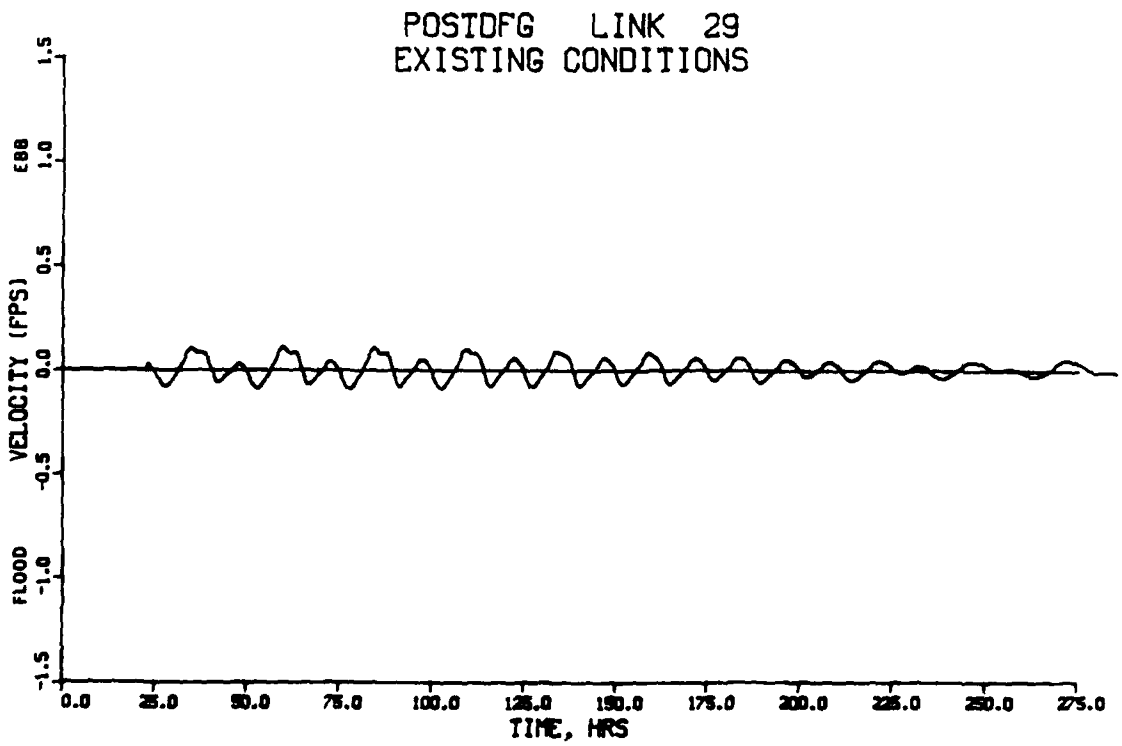

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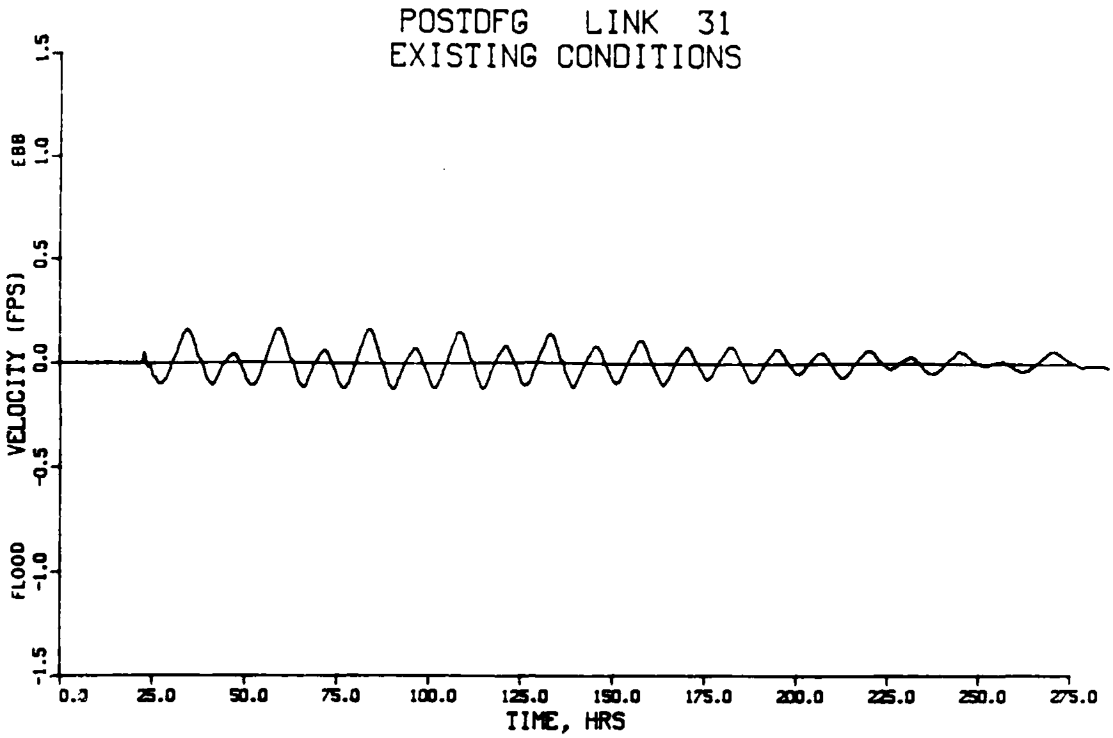

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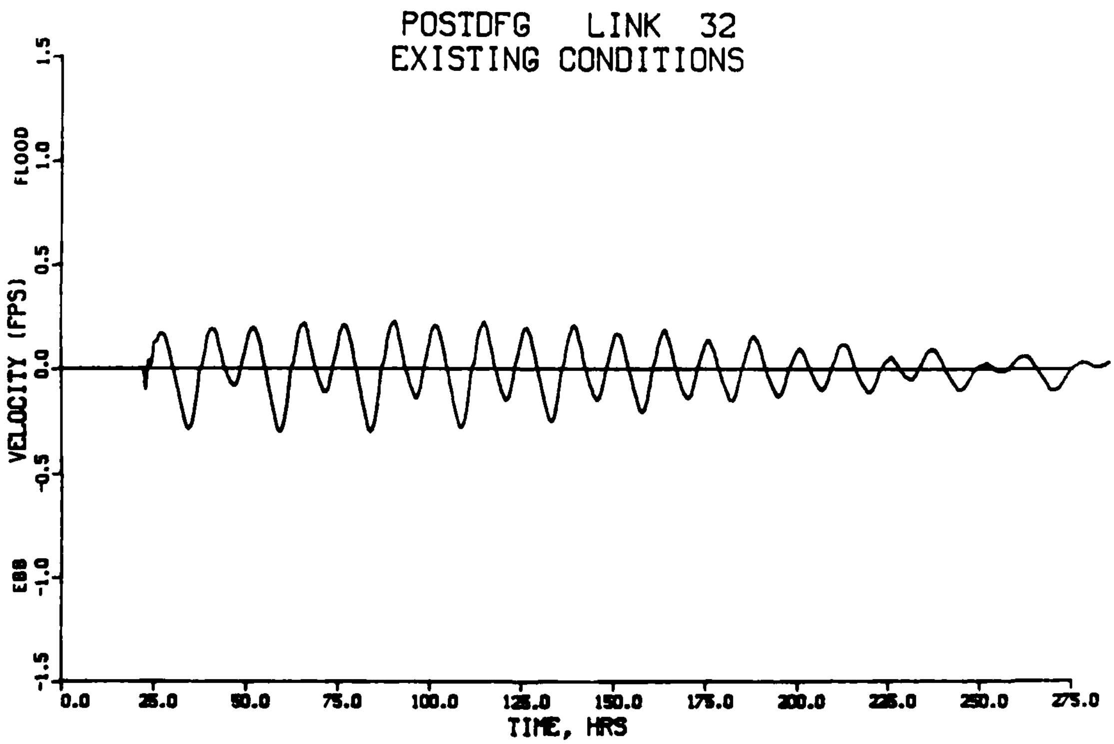

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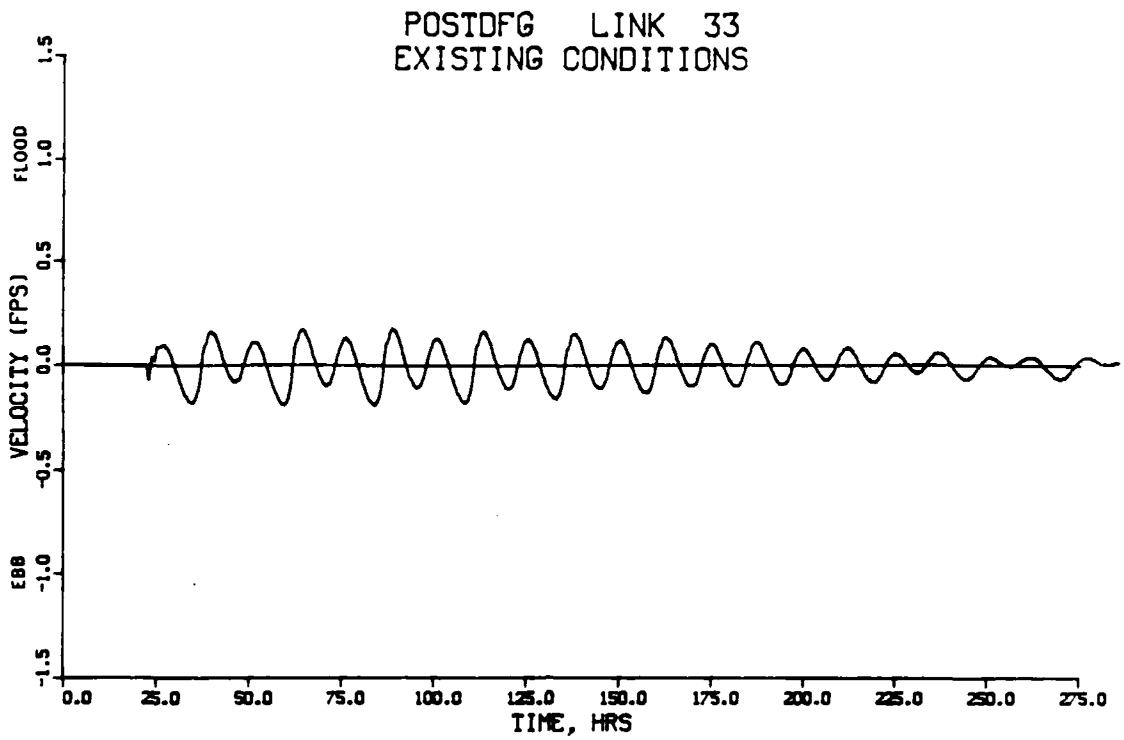

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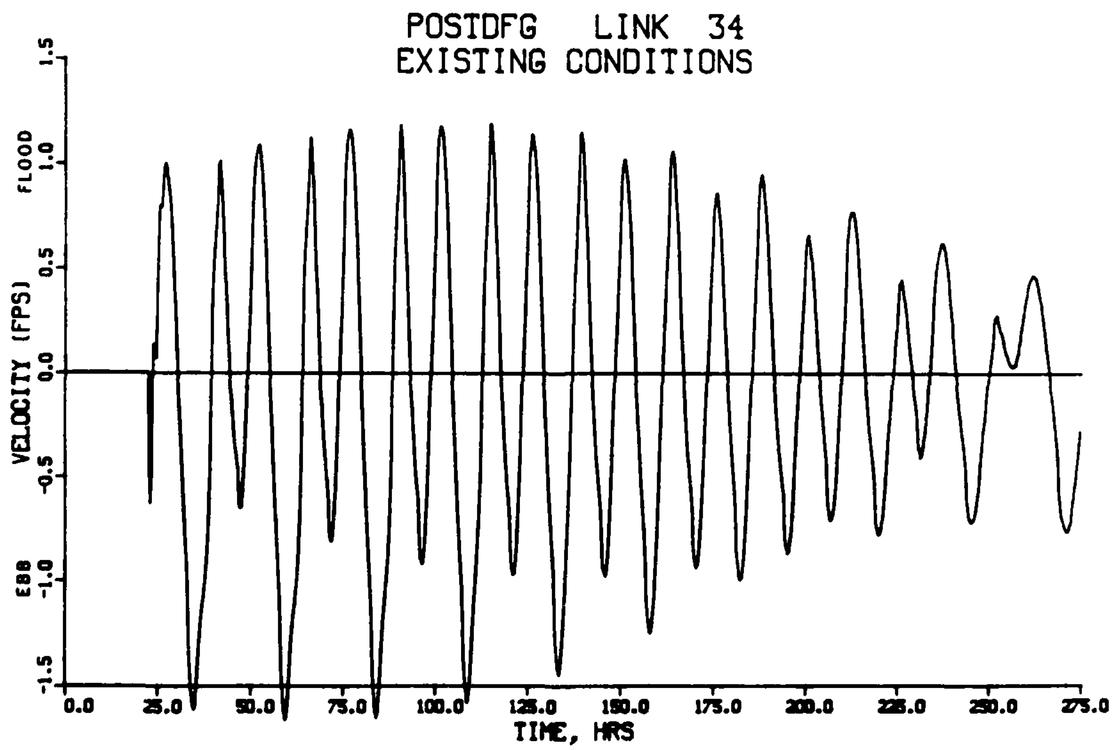

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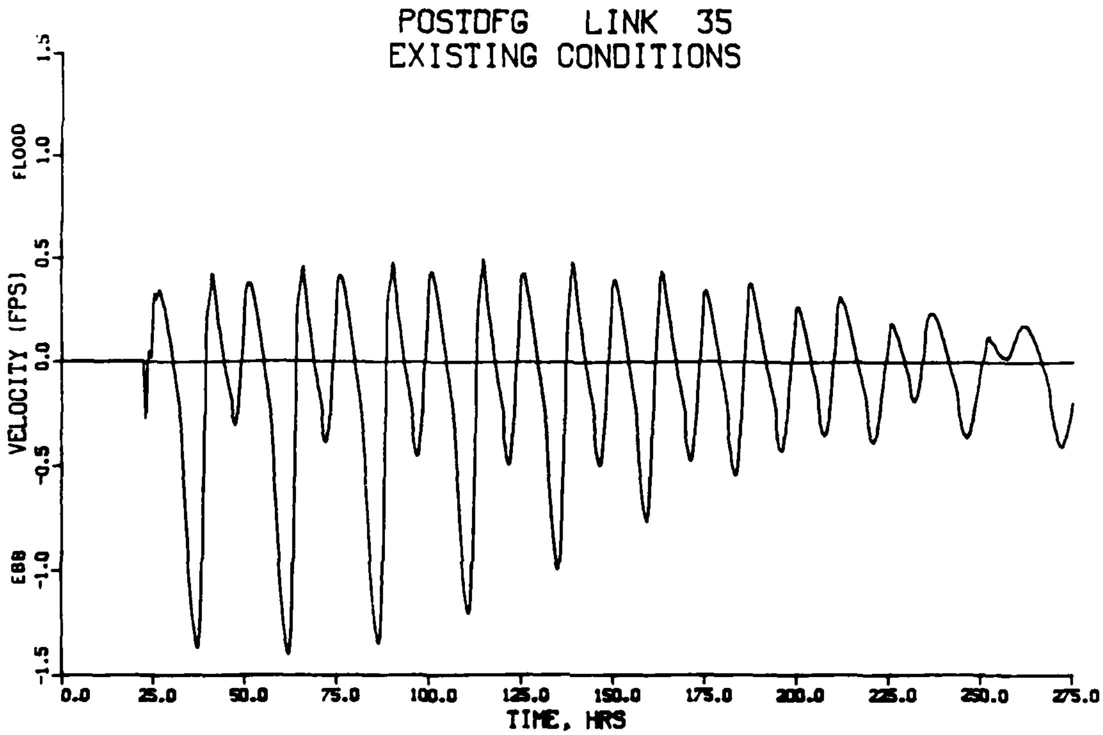


Figure B25. Average channel velocities in Outer Bolsa Bay

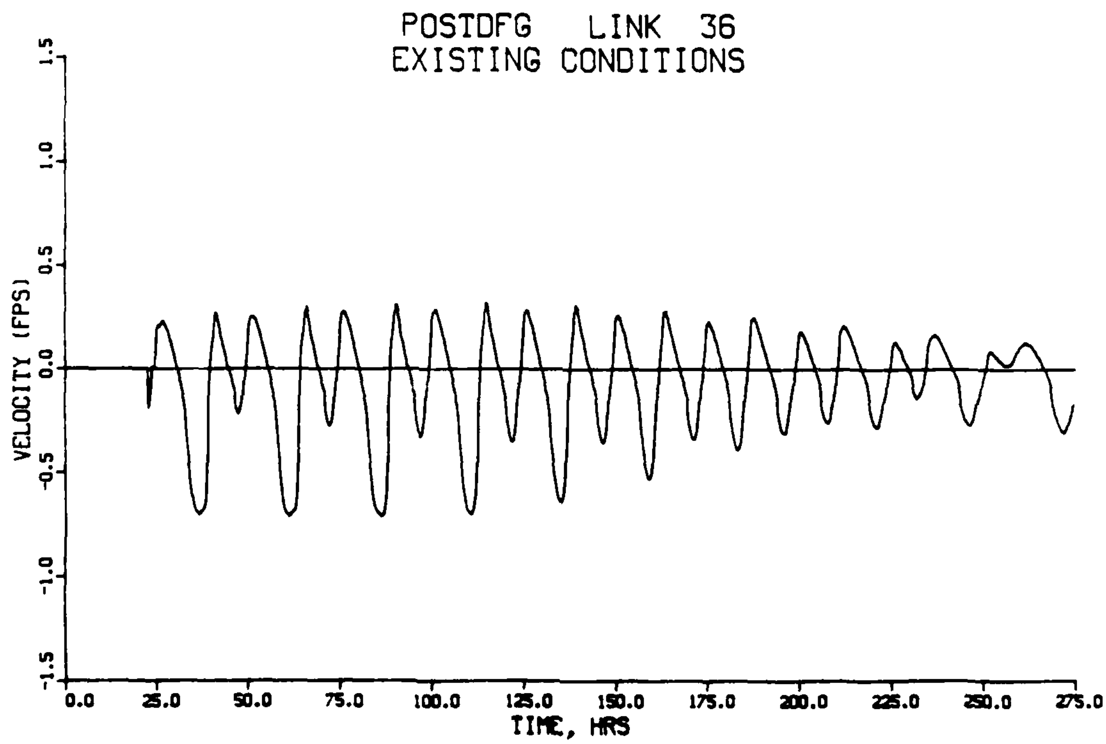


Figure B26. Average channel velocities in Outer Bolsa Bay

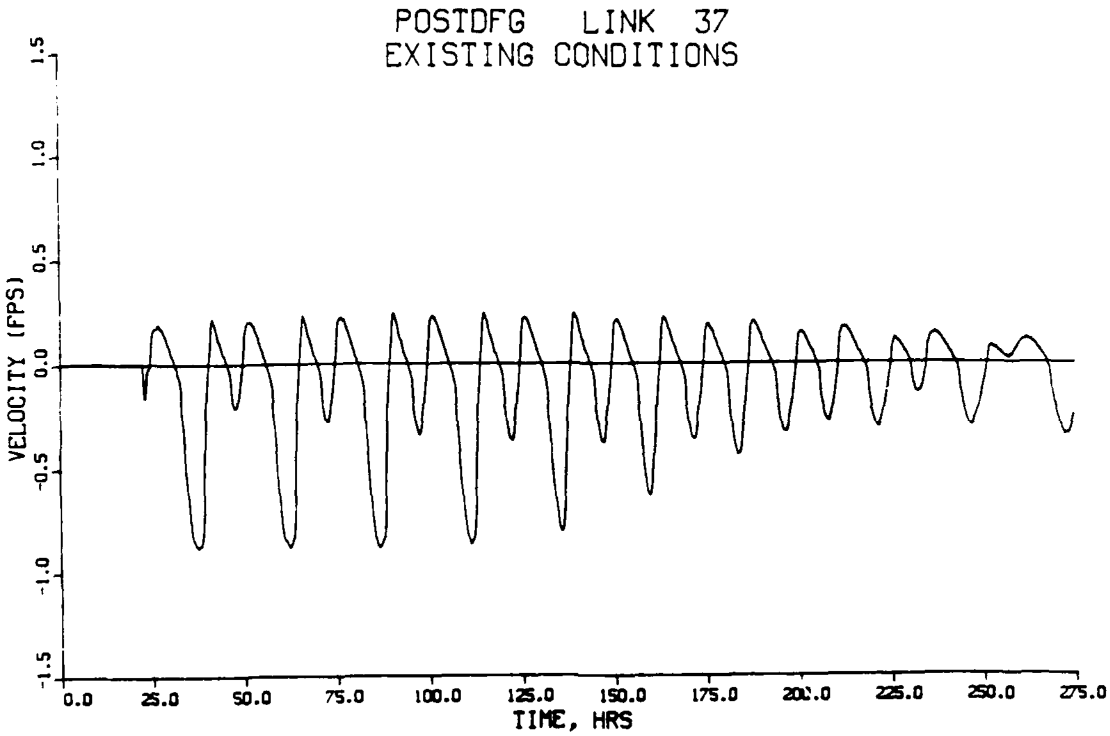


Figure B27. Average channel velocities in Outer Bolsa Bay

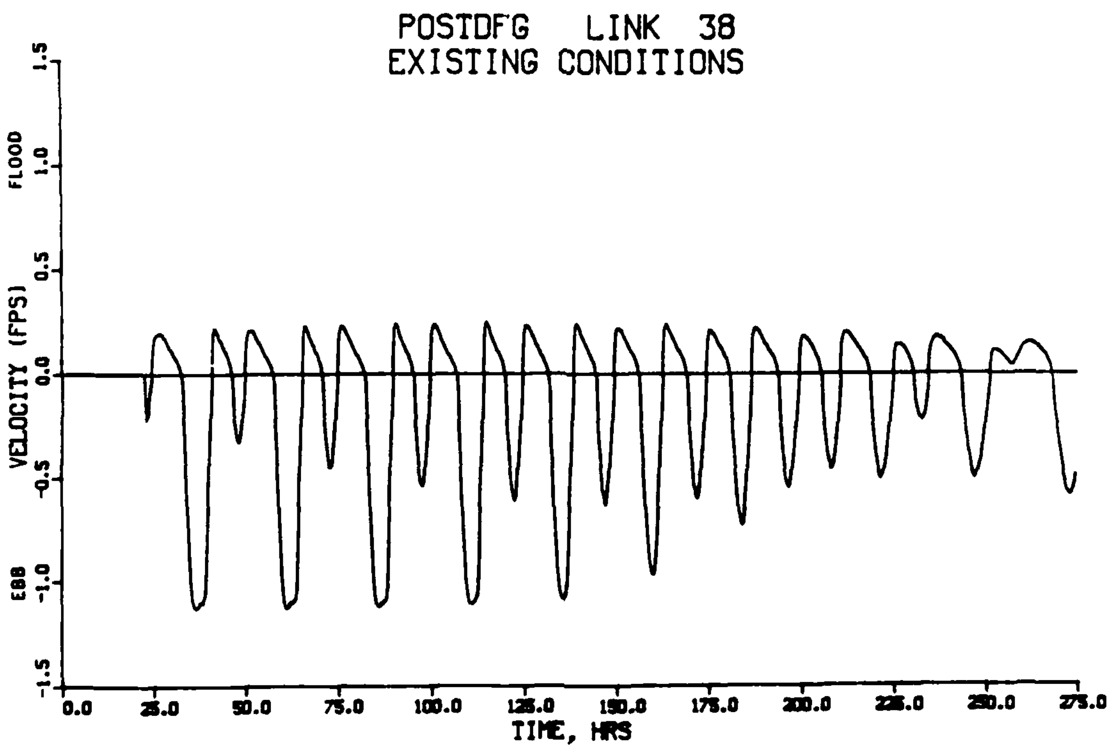


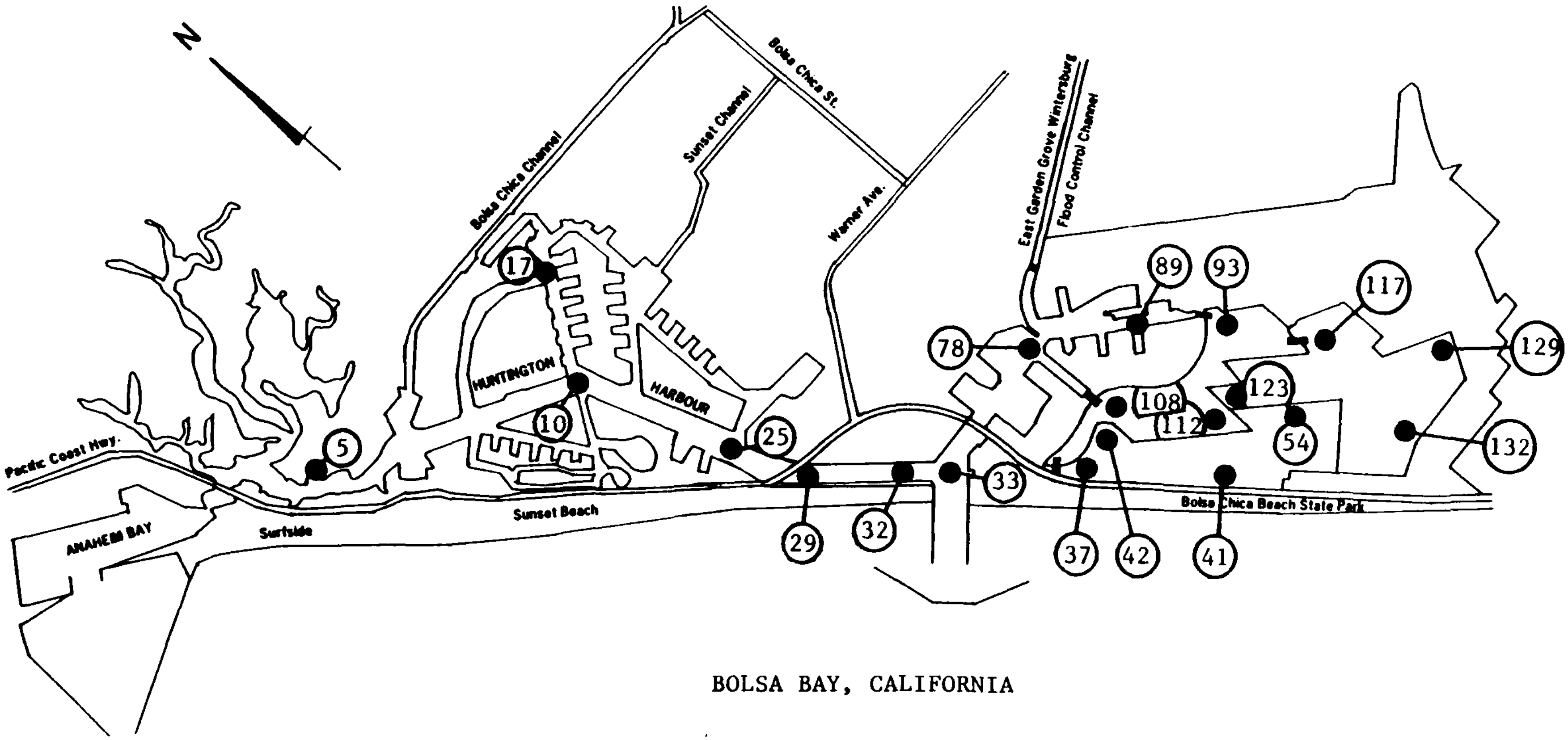
Figure B28. Average channel velocities in Outer Bolsa Bay

APPENDIX C:

NENC1

NAVIGABLE ENTRANCE CHANNEL
AND
NAVIGABLE CONNECTOR CHANNEL TO HUNTINGTON HARBOUR

WATER SURFACE ELEVATIONS



BOLSA BAY, CALIFORNIA

NENC1
Location of nodes for displaying water surface elevations
under navigable entrance channel and navigable connector channel to Huntington Harbour conditions

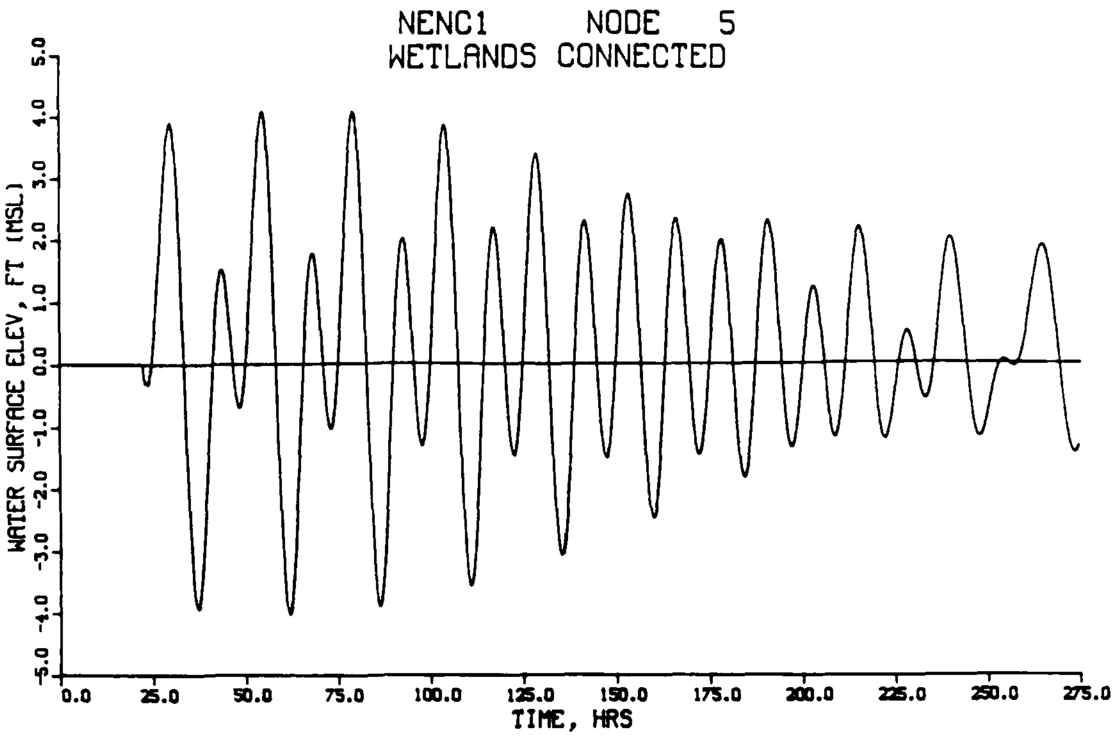


Figure C1. Tidal elevations in Huntington Harbour under navigable entrance, navigable connector conditions

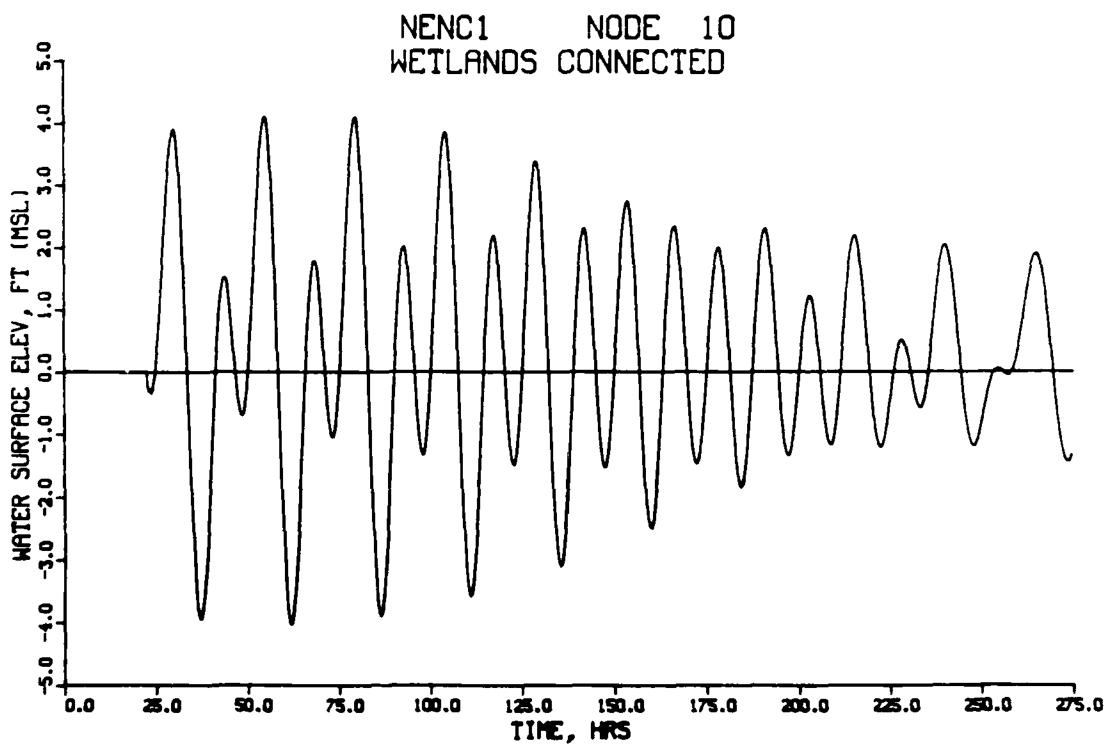


Figure C2. Tidal elevations in Huntington Harbour under navigable entrance, navigable connector conditions

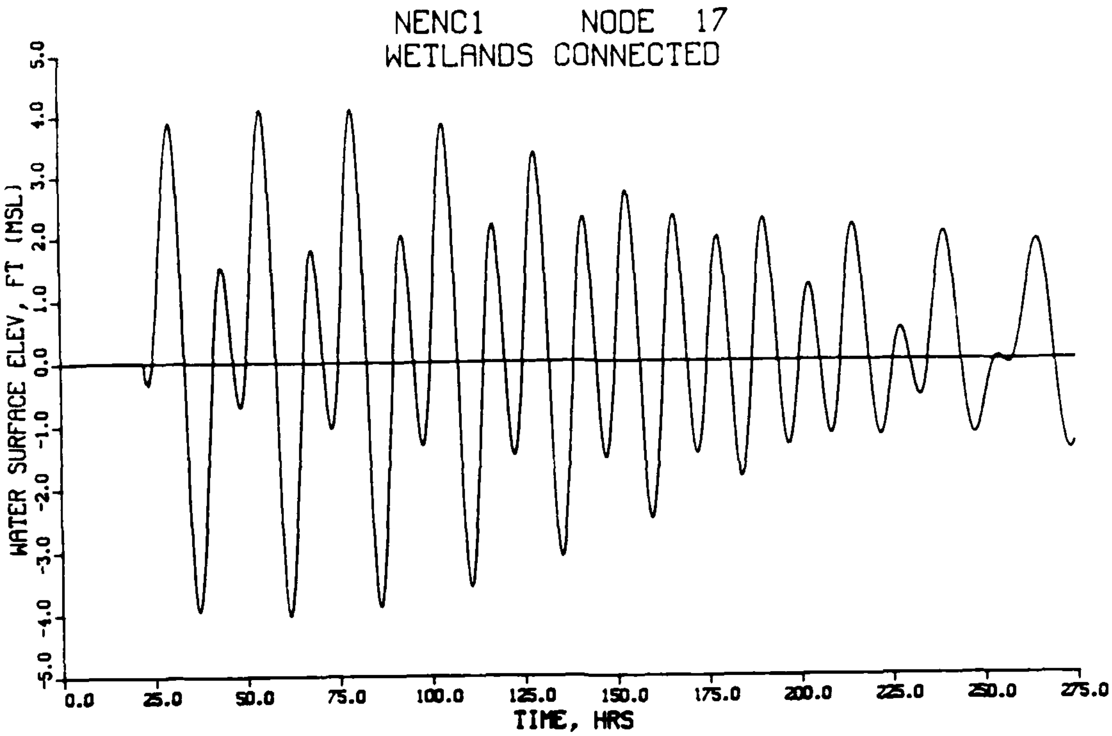


Figure C3. Tidal elevations in Huntington Harbour under navigable entrance, navigable connector conditions

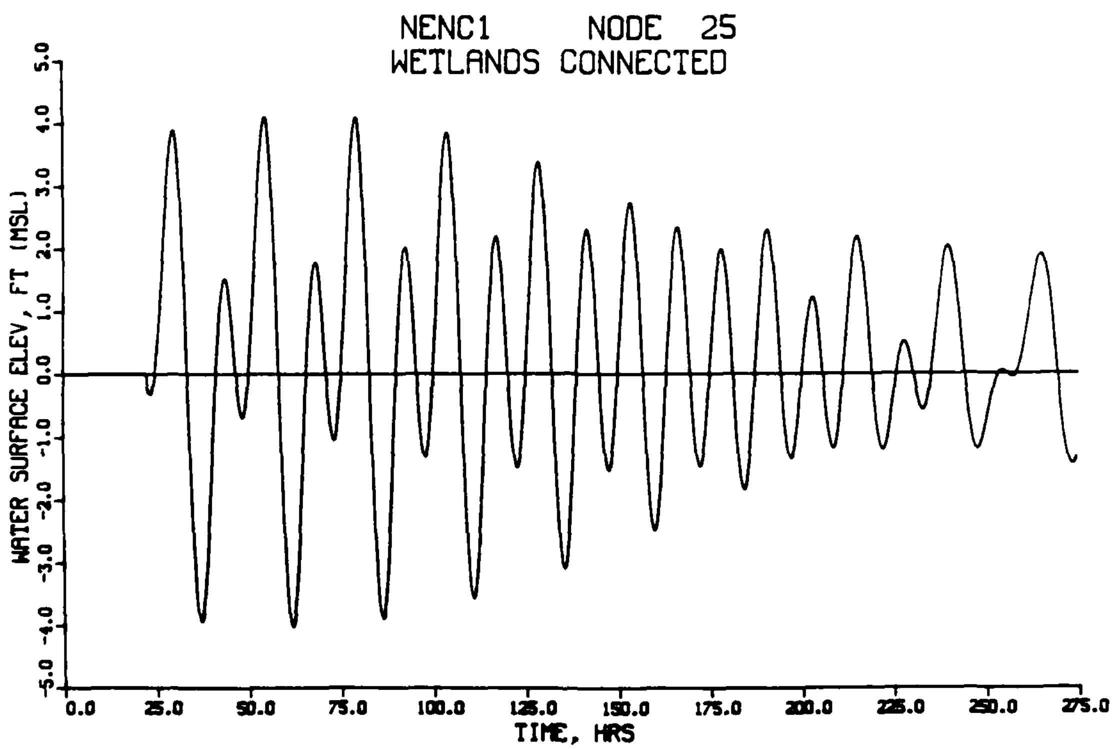


Figure C4. Tidal elevations in Huntington Harbour under navigable entrance, navigable connector conditions

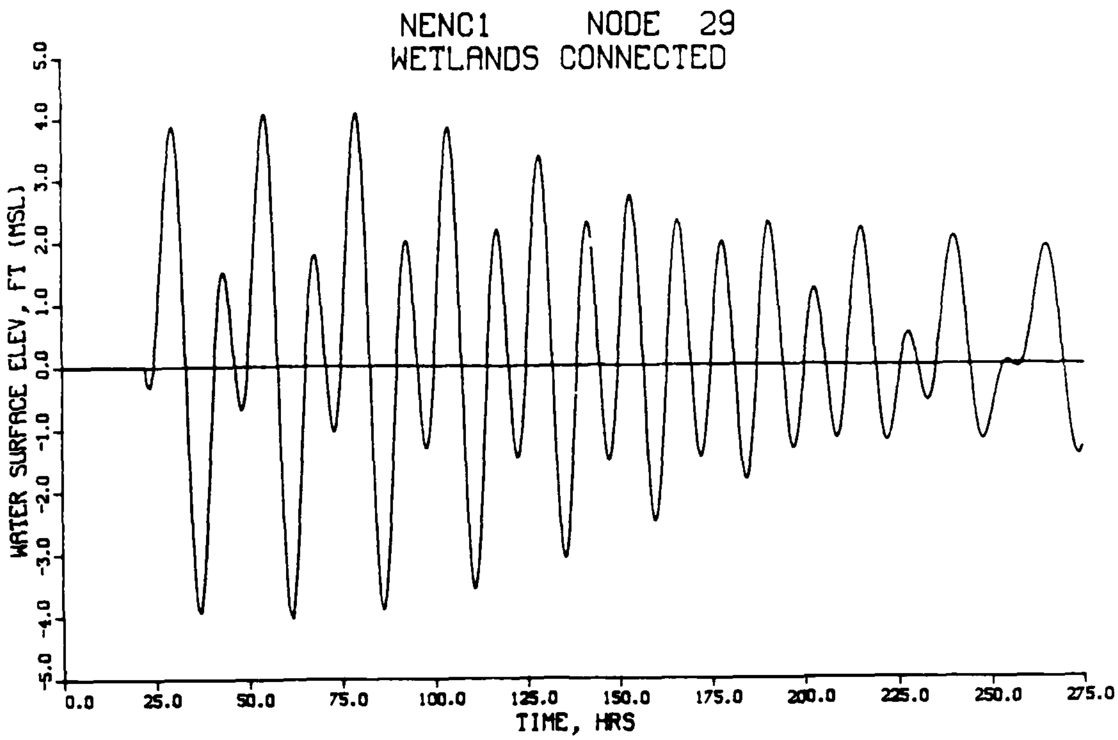


Figure C5. Tidal elevations in Outer Bolsa Bay under navigable entrance, navigable connector conditions

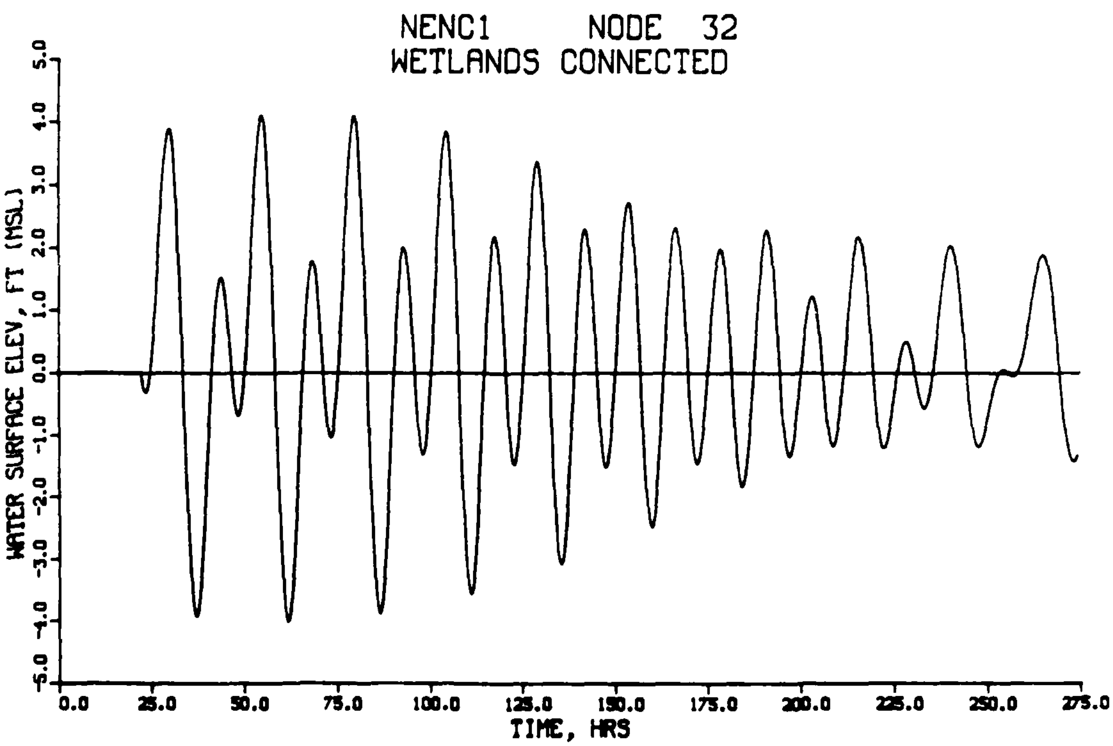


Figure C6. Tidal elevations in Outer Bolsa Bay under navigable entrance, navigable connector conditions

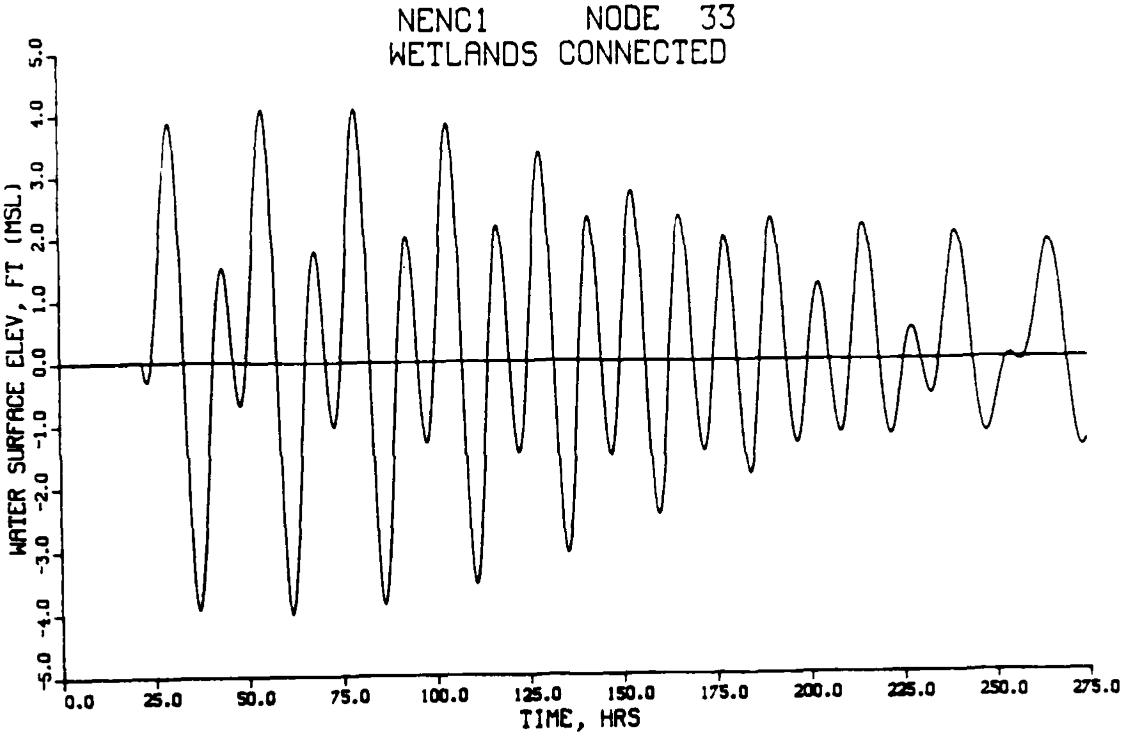


Figure C7. Tidal elevations in entrance channel under navigable entrance, navigable connector conditions

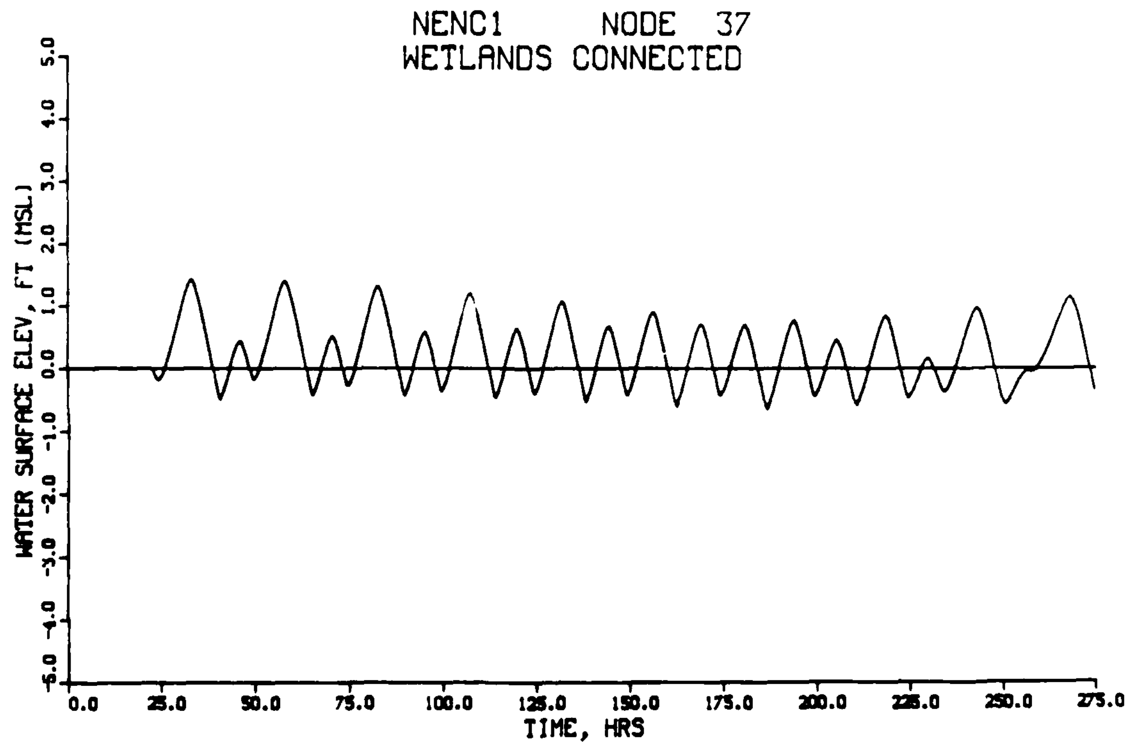


Figure C8. Tidal elevations in Inner Bolsa Bay under navigable entrance, navigable connector conditions

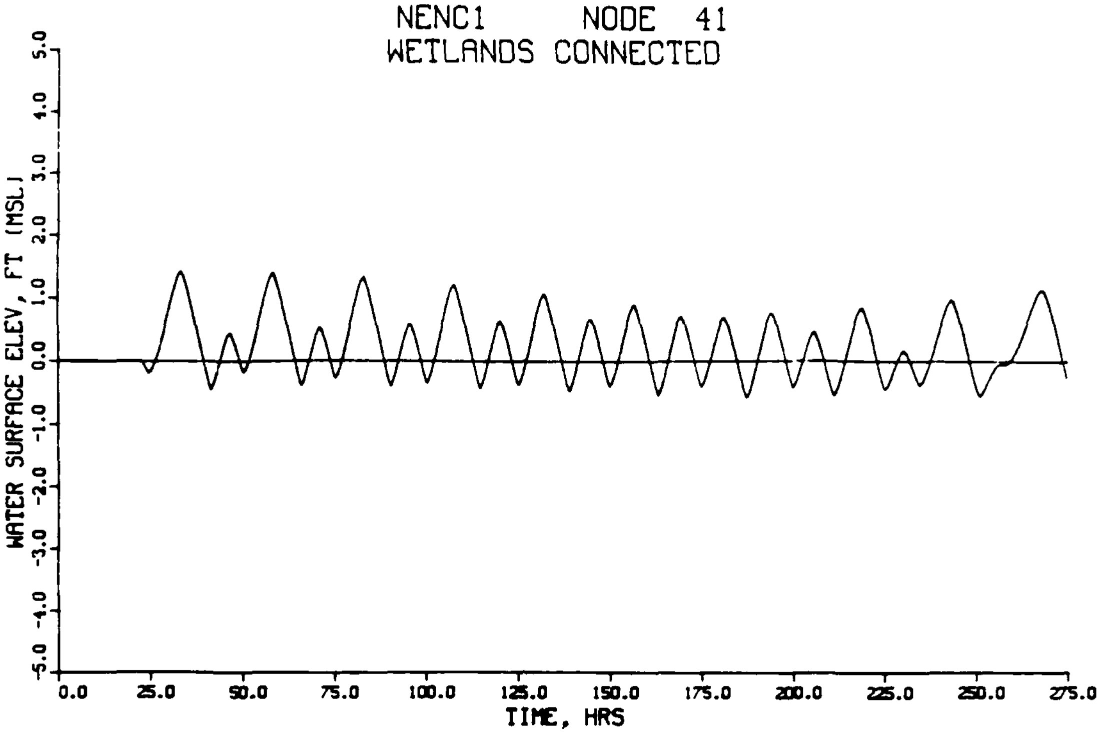


Figure C9. Tidal elevations in Inner Bolsa Bay under navigable entrance, navigable connector conditions

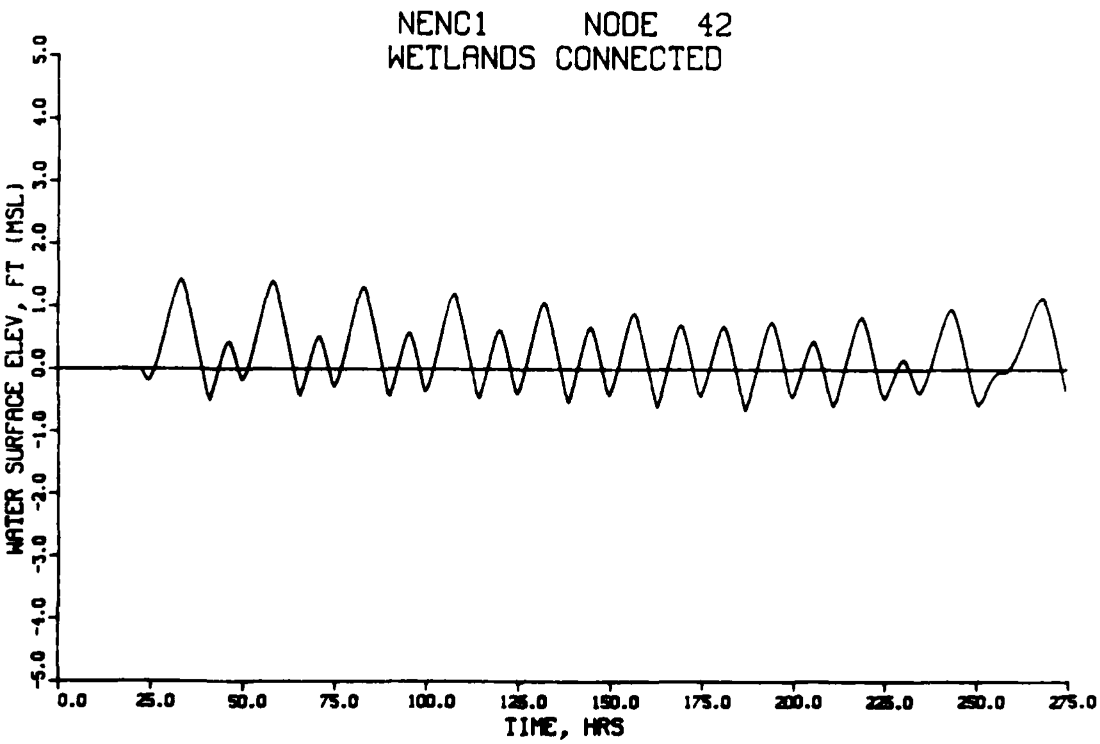


Figure C10. Tidal elevations in Inner Bolsa Bay under navigable entrance, navigable connector conditions

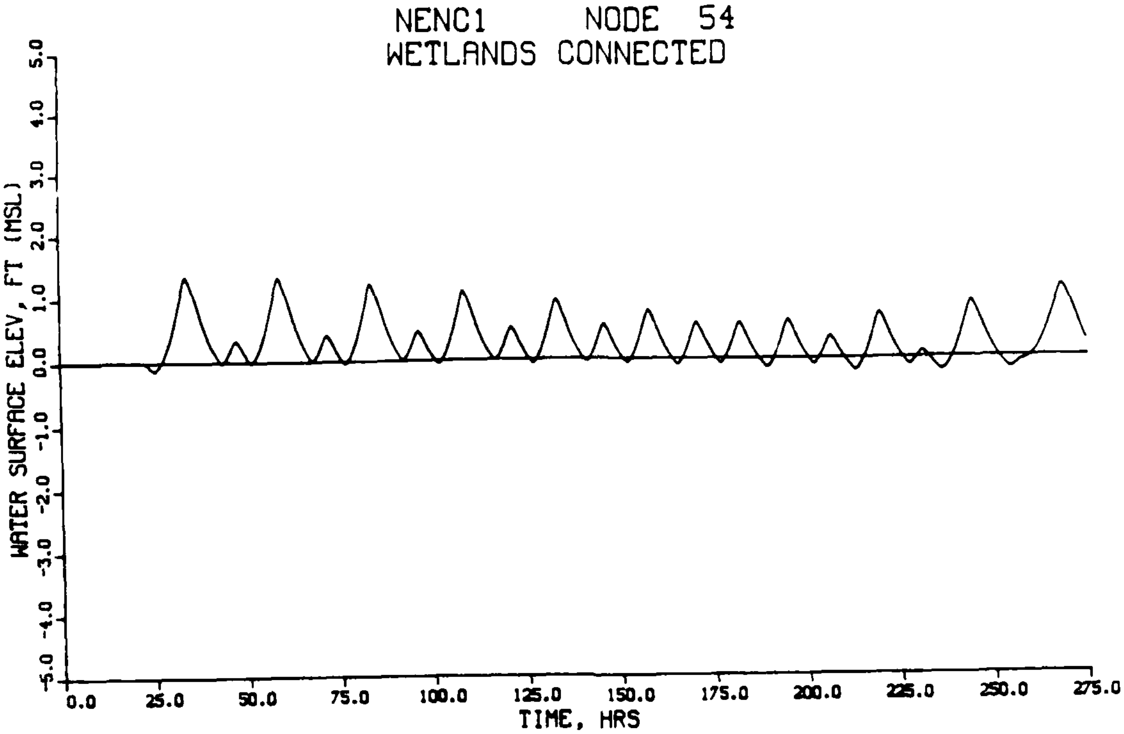


Figure C11. Tidal elevations in DFG muted tidal cell under navigable entrance, navigable connector conditions

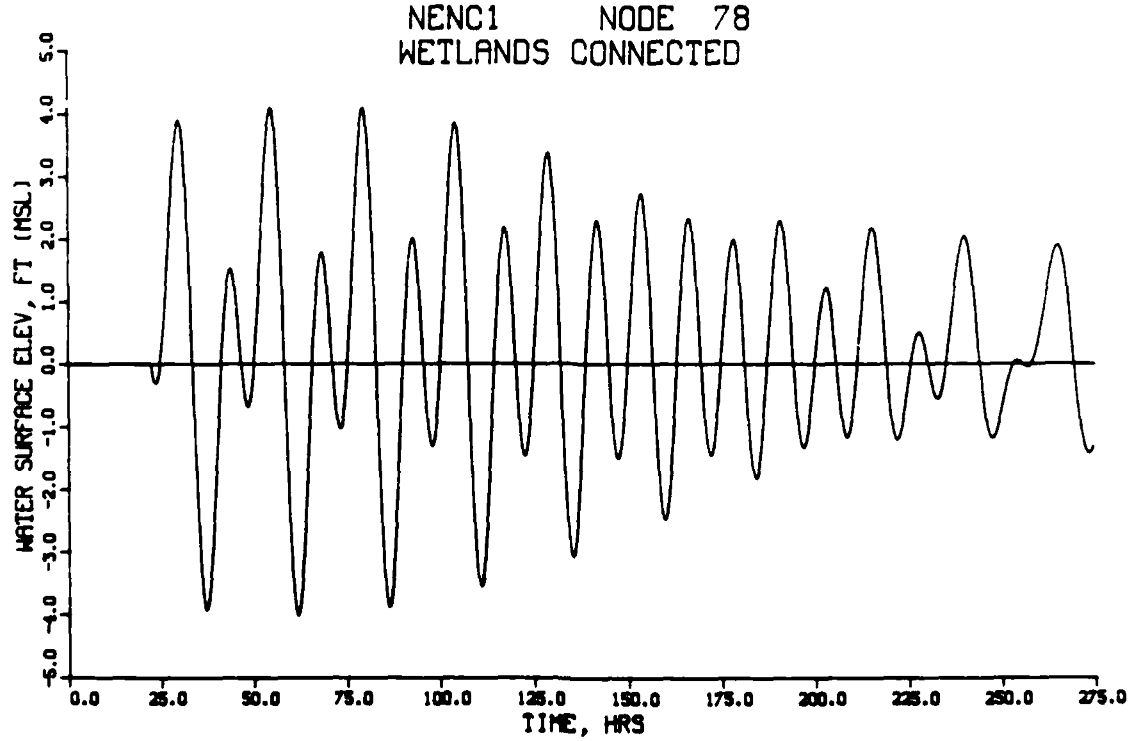


Figure C12. Tidal elevations in proposed marina channel under navigable entrance, navigable connector conditions

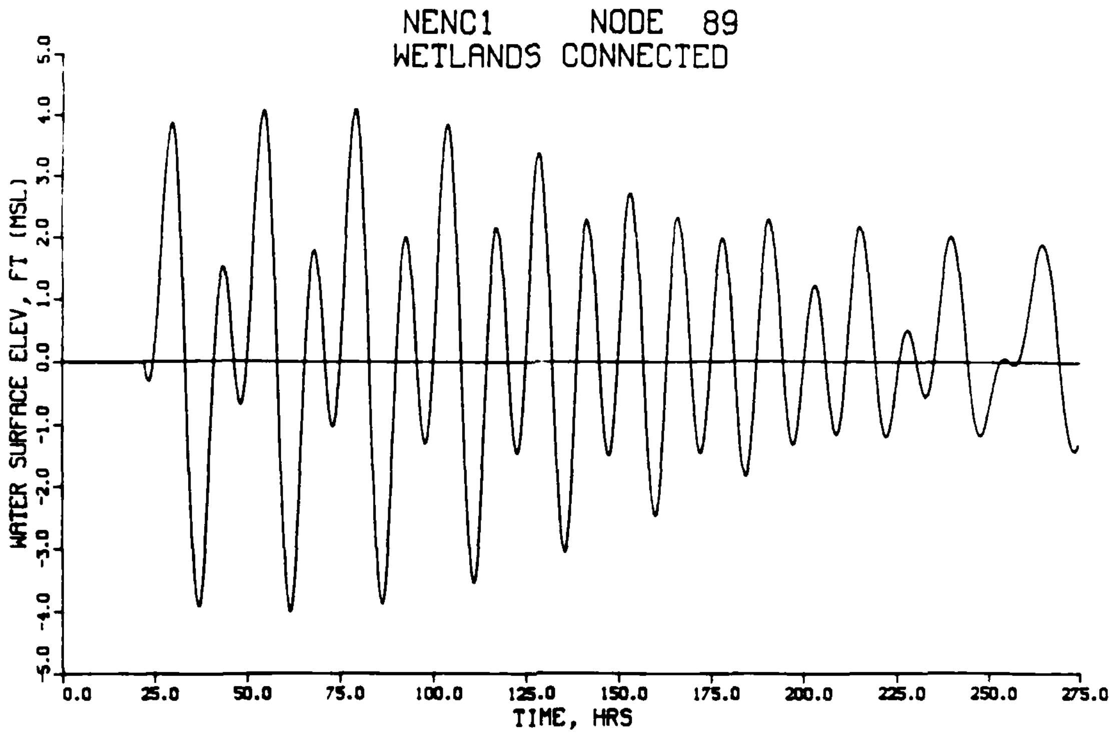


Figure C13. Tidal elevations in proposed marina channel under navigable entrance, navigable connector conditions

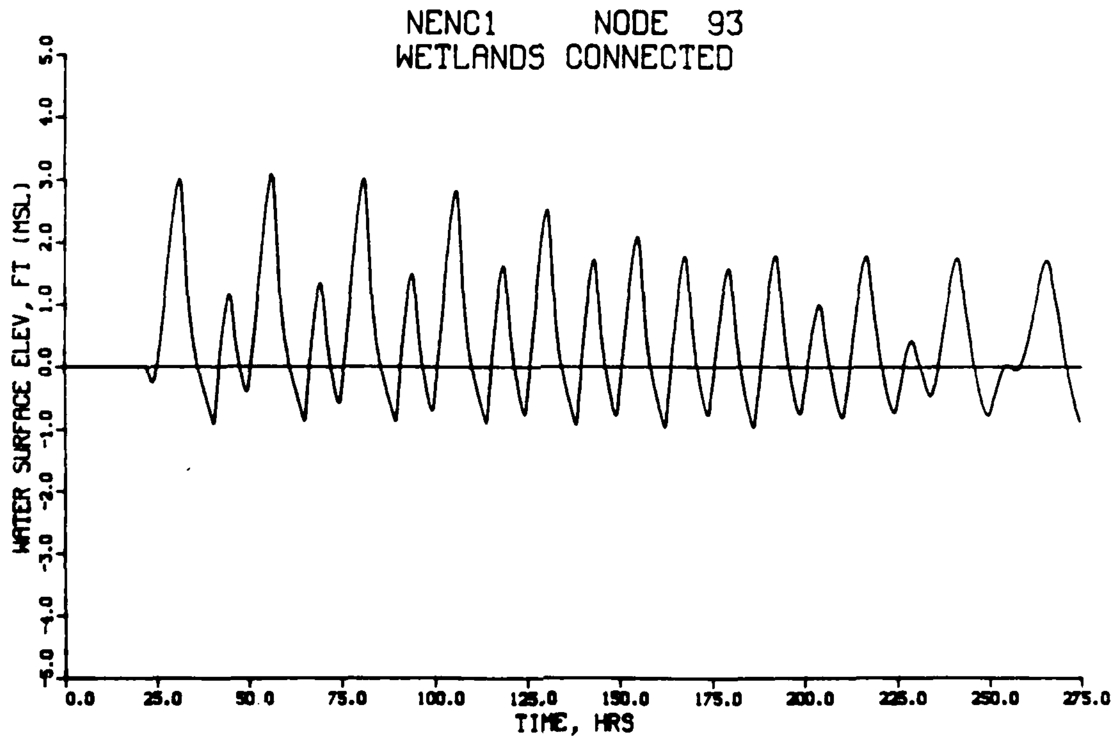


Figure C14. Tidal elevations in proposed full tidal wetlands under navigable entrance, navigable connector conditions

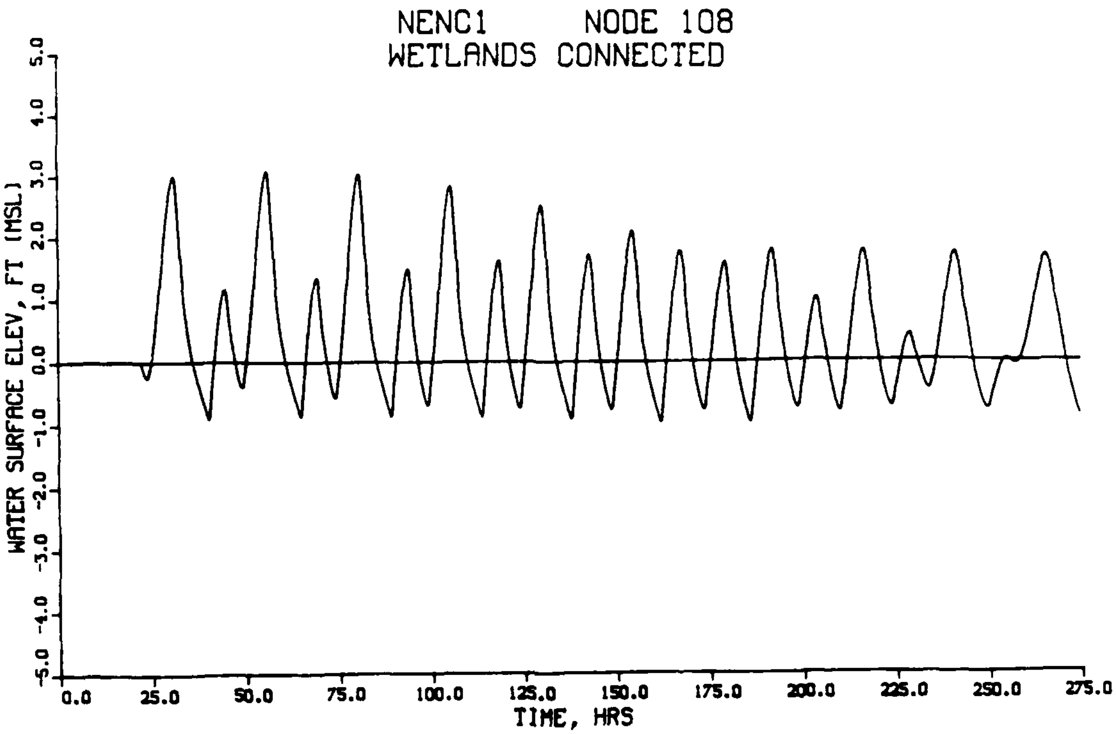


Figure C15. Tidal elevations in proposed full tidal wetlands under navigable entrance, navigable connector conditions

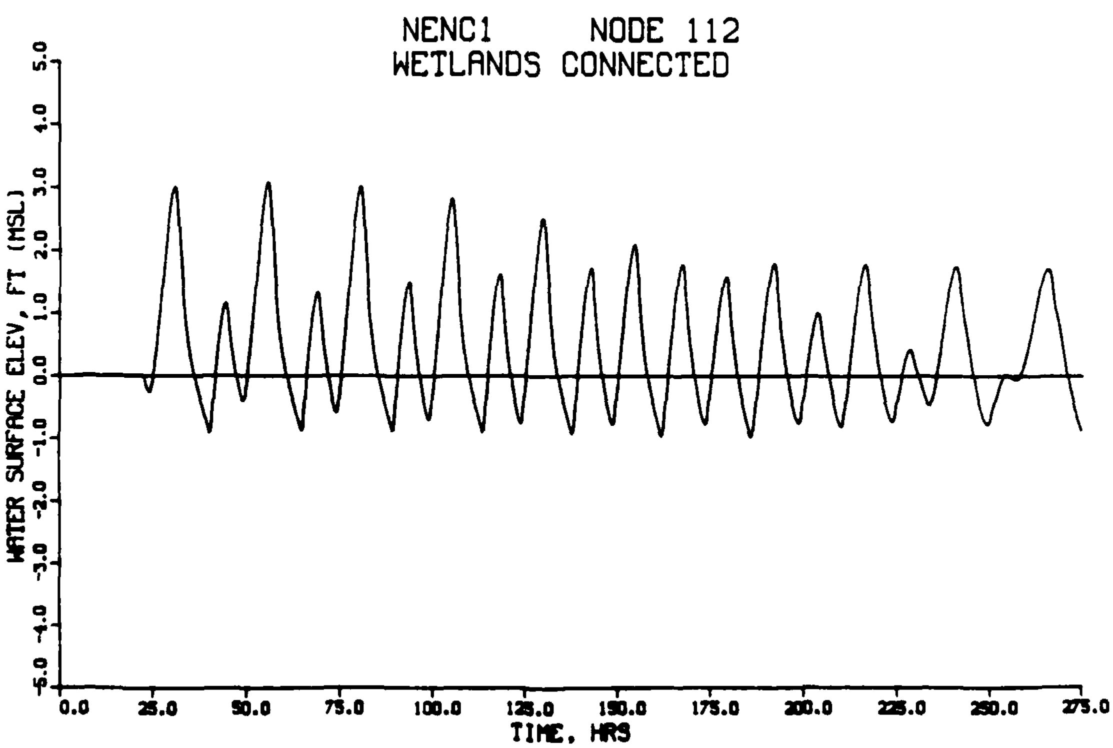


Figure C16. Tidal elevations in proposed full tidal wetlands under navigable entrance, navigable connector conditions

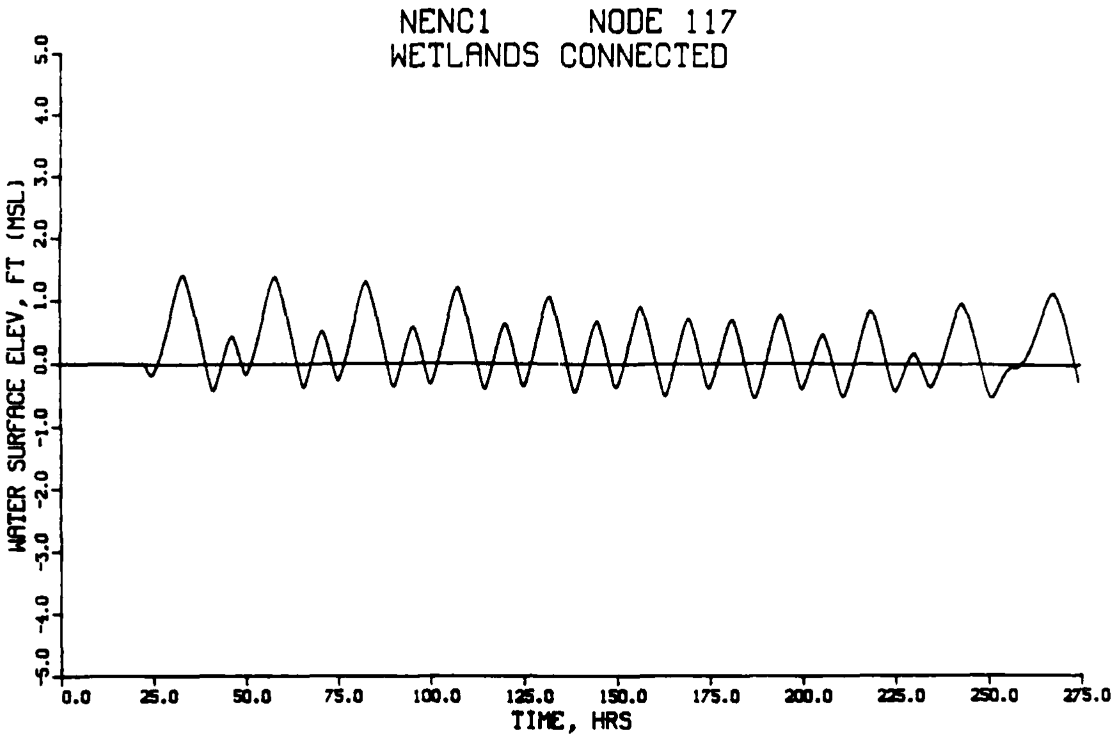


Figure C17. Tidal elevations in proposed muted tidal wetlands under navigable entrance, navigable connector conditions

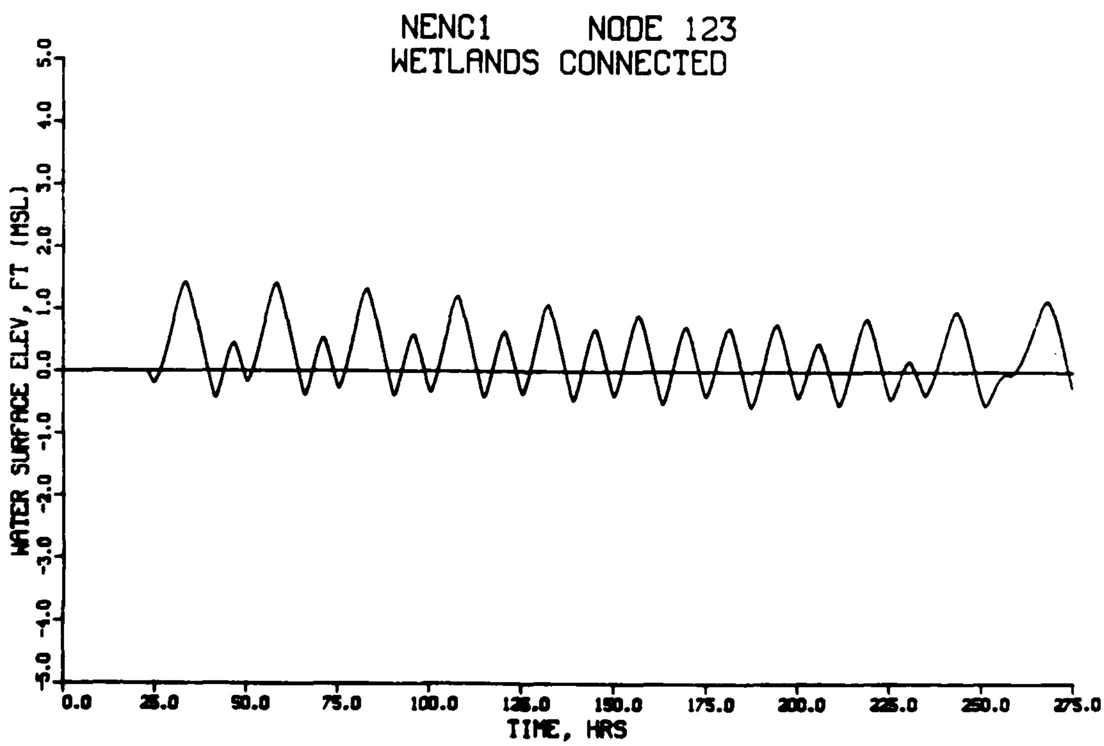


Figure C18. Tidal elevations in proposed muted tidal wetlands under navigable entrance, navigable connector conditions

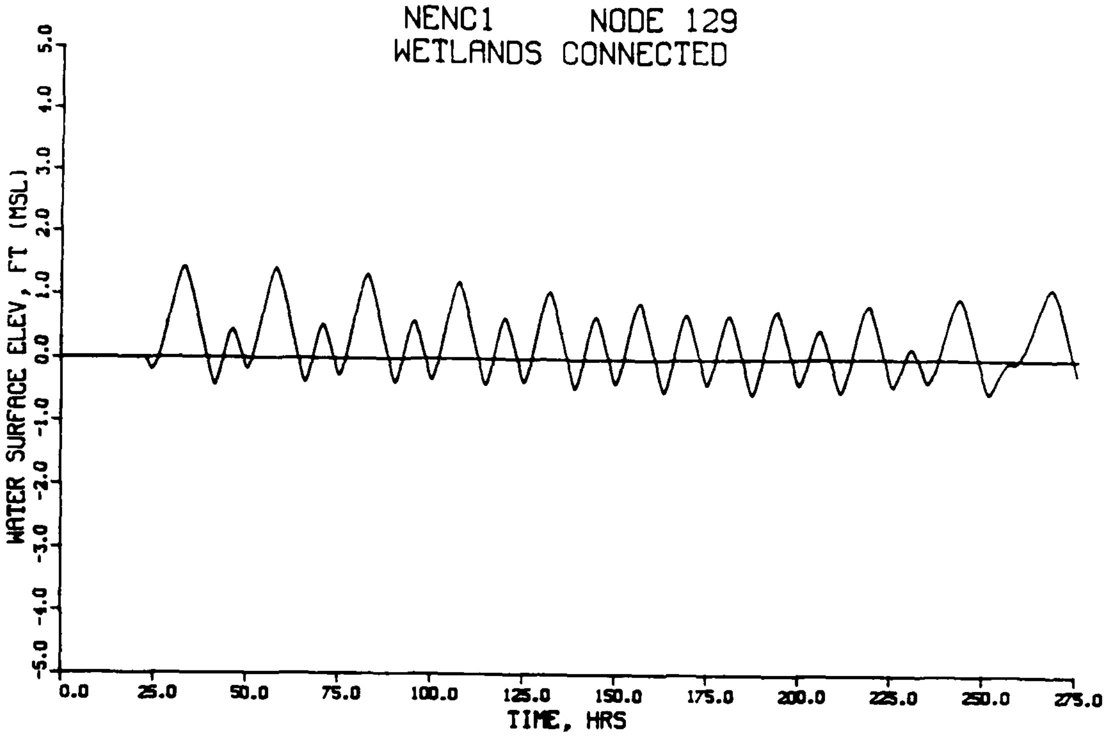


Figure C19. Tidal elevations in proposed muted tidal wetlands under navigable entrance, navigable connector conditions

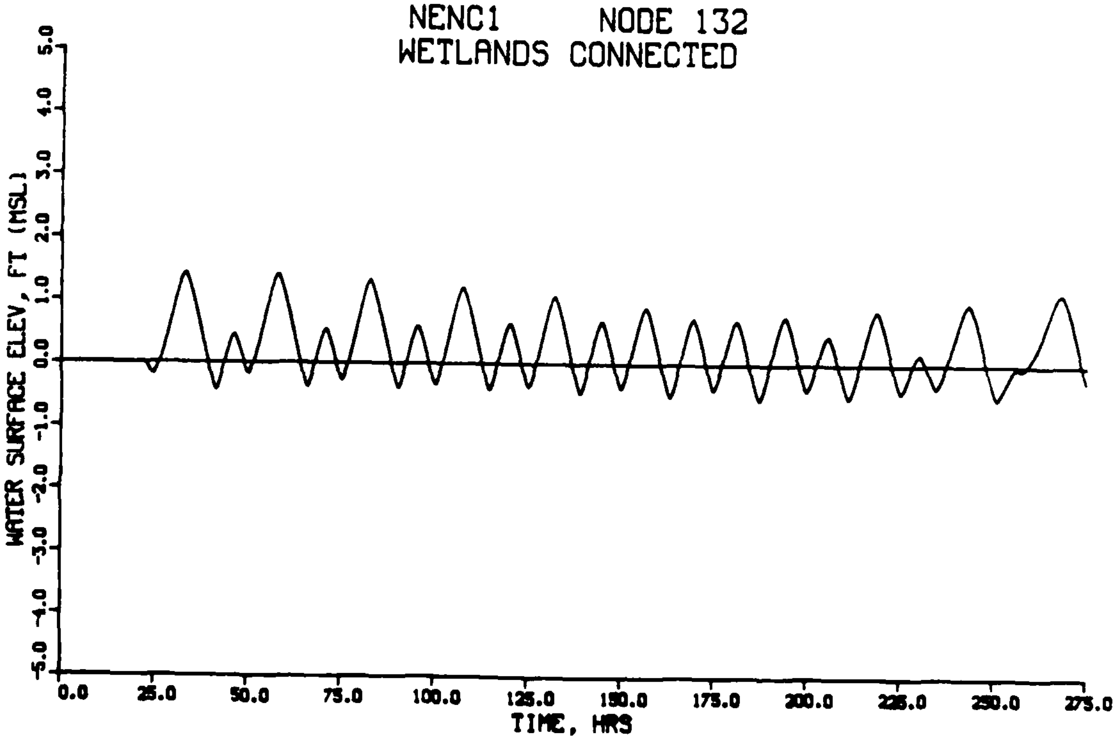


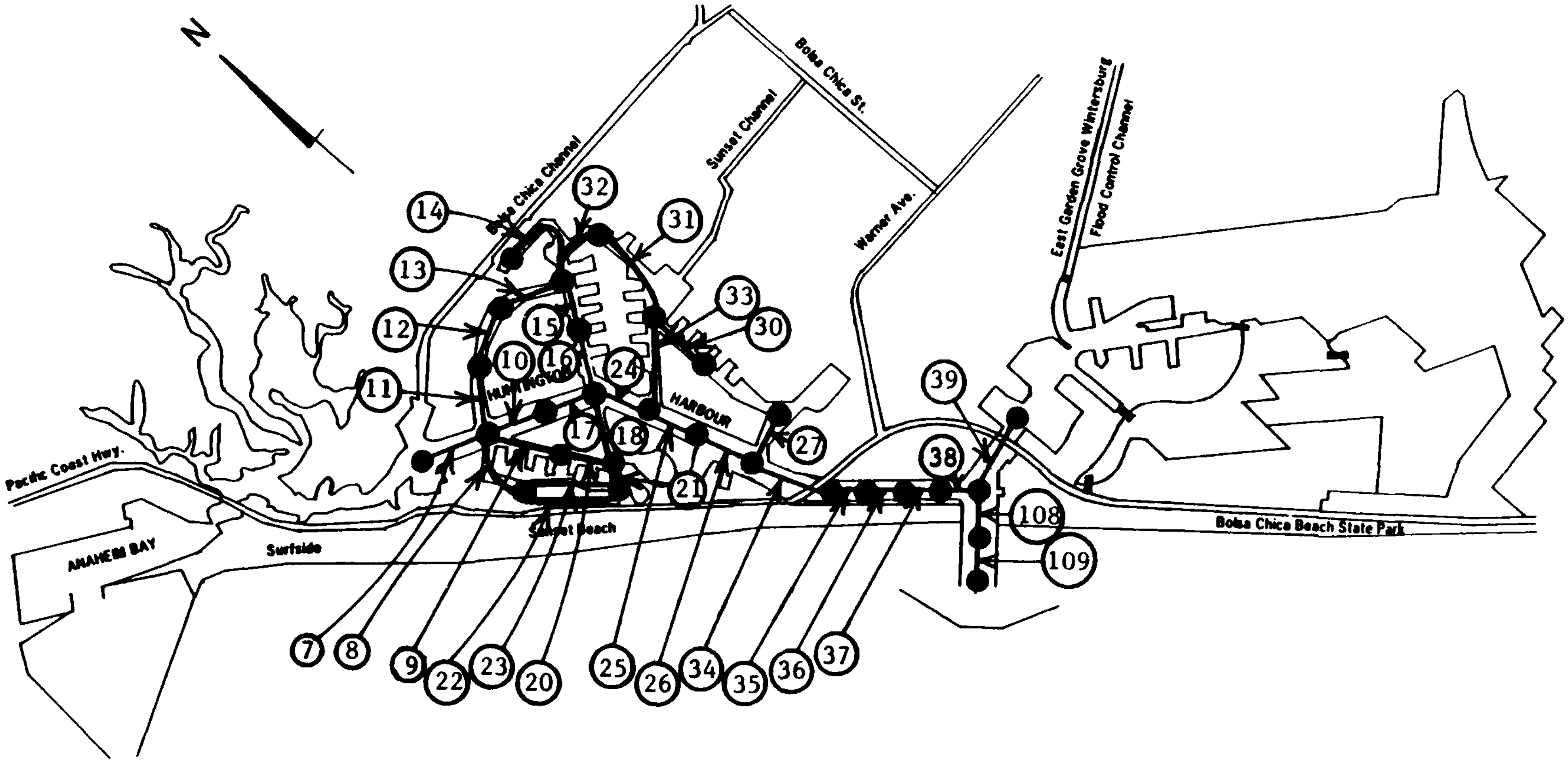
Figure C20. Tidal elevations in proposed muted tidal wetlands under navigable entrance, navigable connector conditions

APPENDIX D:

NENC1

NAVIGABLE ENTRANCE CHANNEL
AND
NAVIGABLE CONNECTOR CHANNEL TO HUNTINGTON HARBOUR

AVERAGE CHANNEL VELOCITIES



BOLSA BAY, CALIFORNIA

NENC1
Location of links for displaying average channel velocities
under navigable entrance channel and navigable connector channel to Huntington Harbour conditions

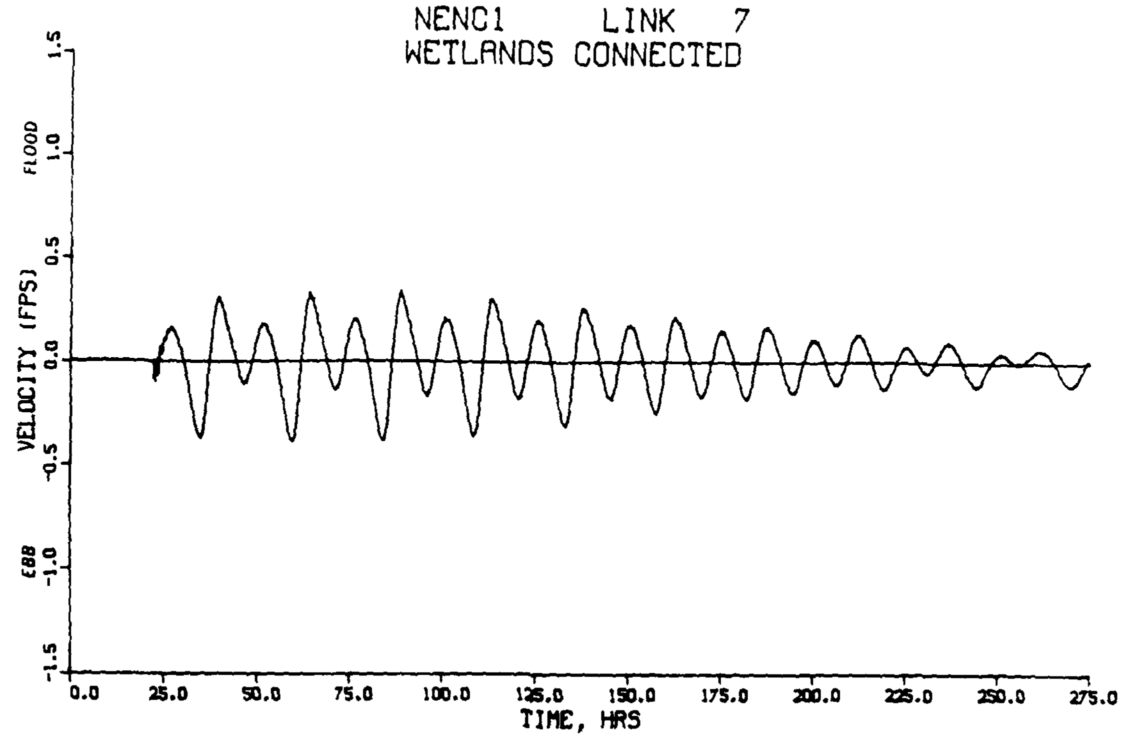


Figure D1. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

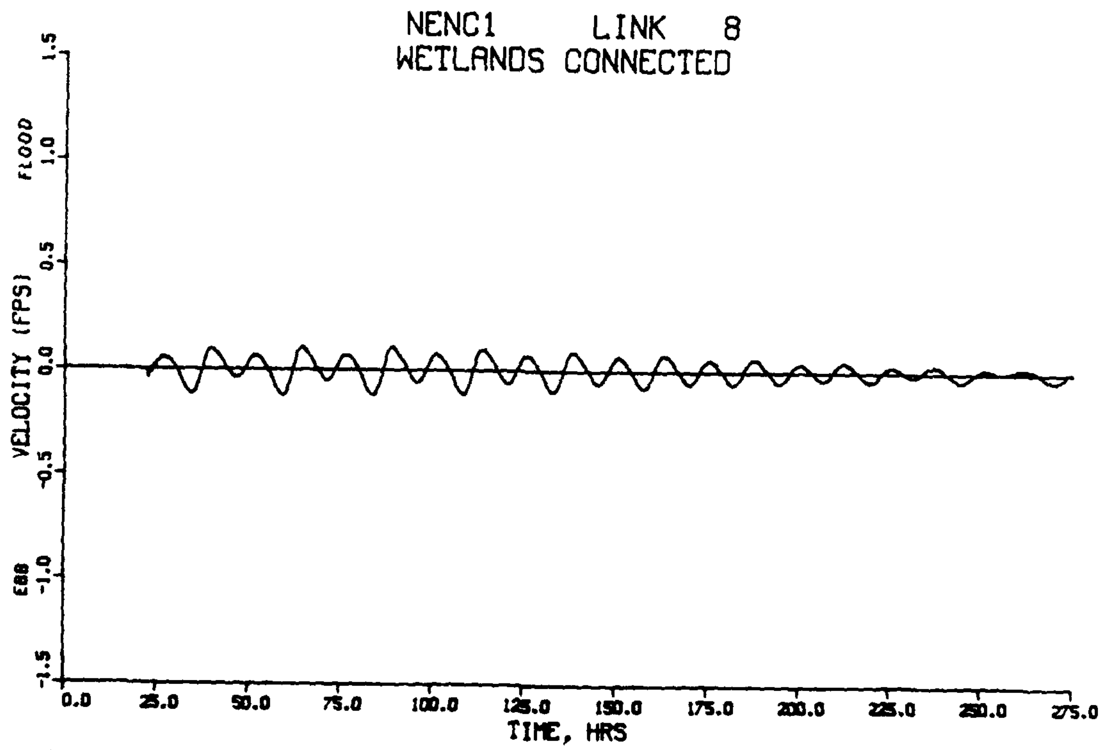


Figure D2. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

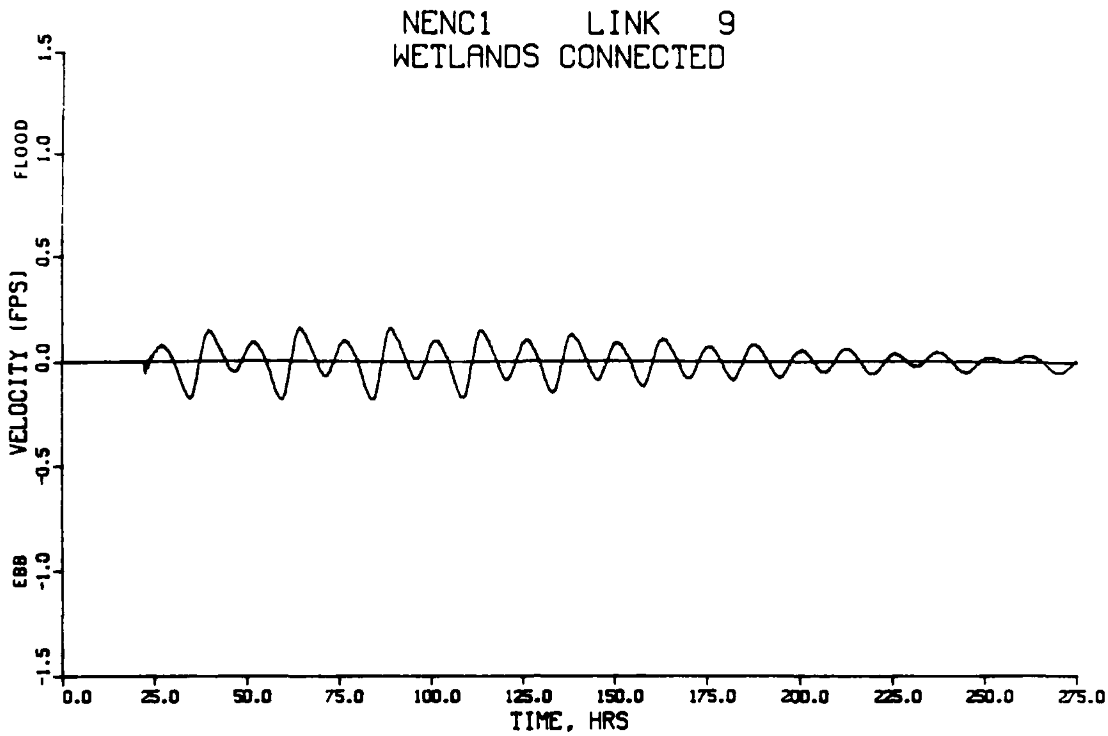


Figure D3. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

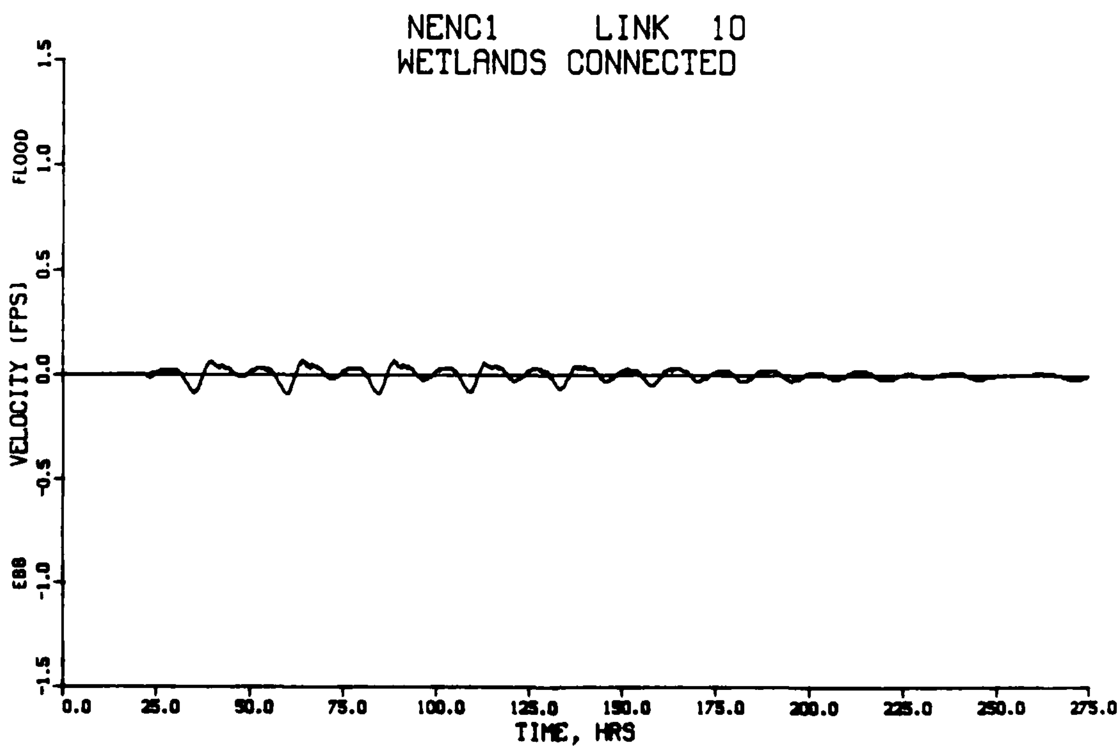


Figure D4. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

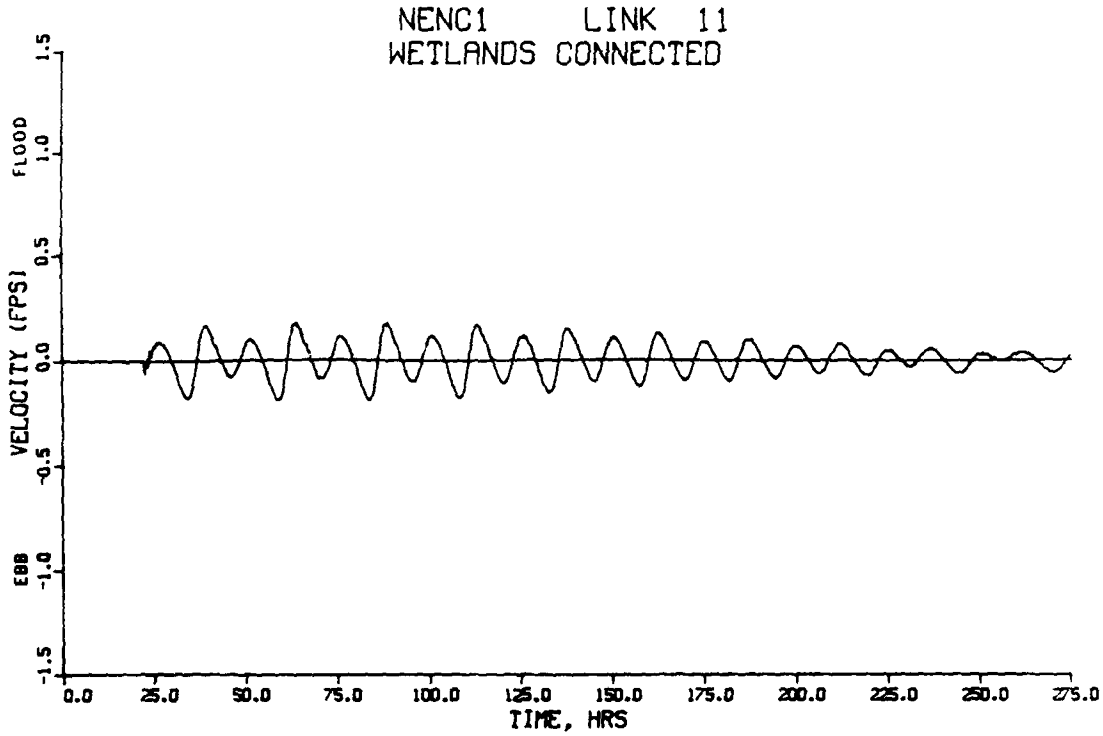


Figure D5. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

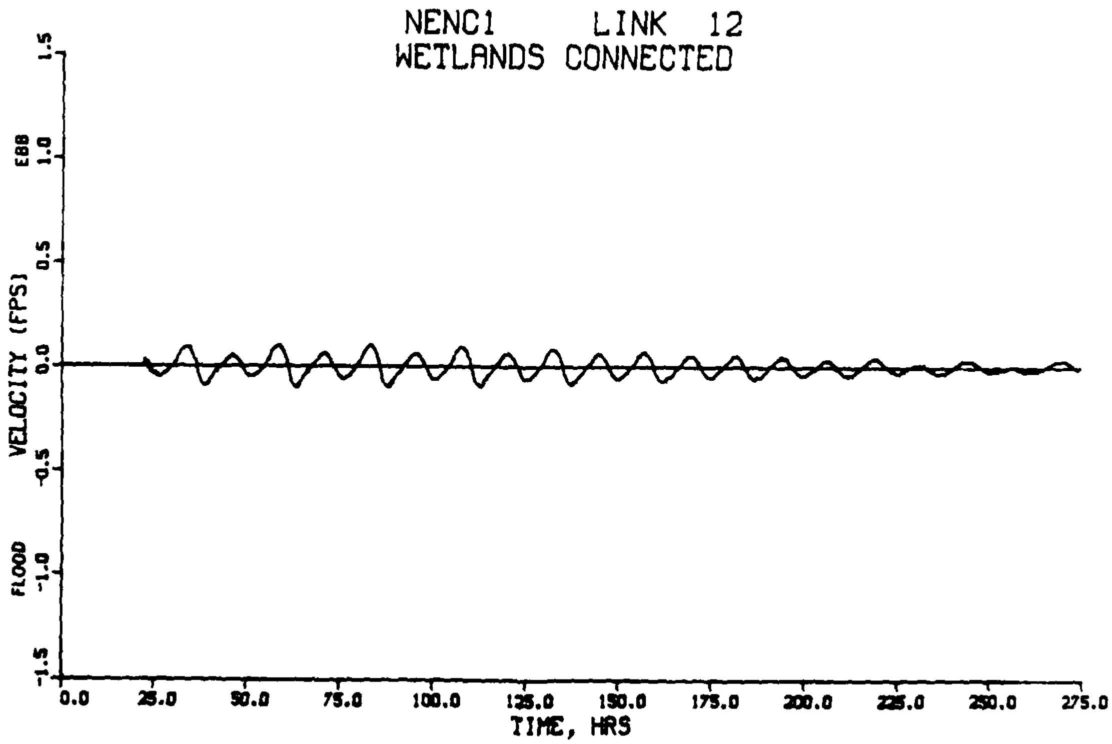


Figure D6. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

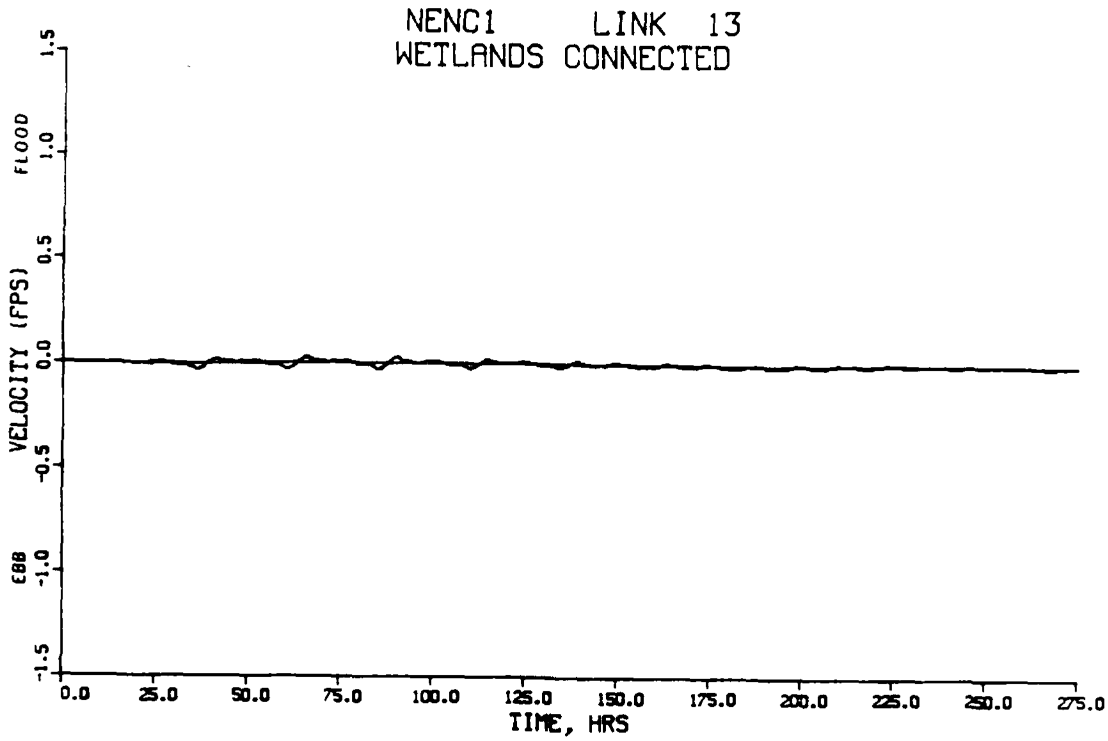


Figure D7. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

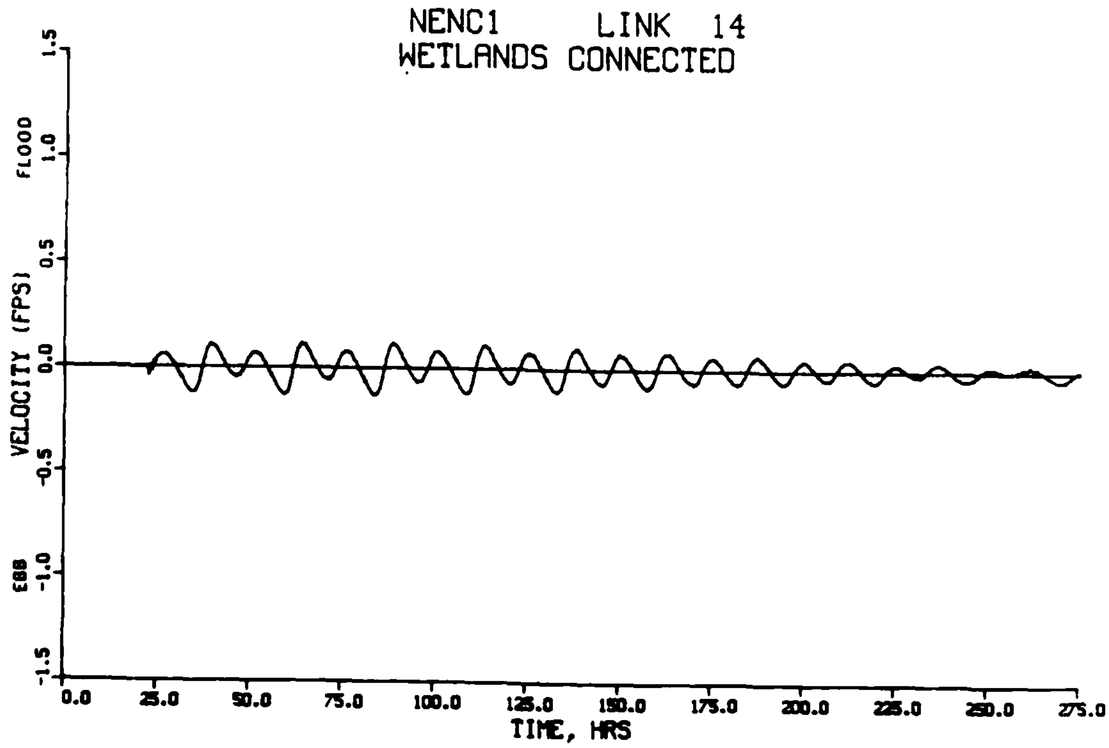


Figure D8. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

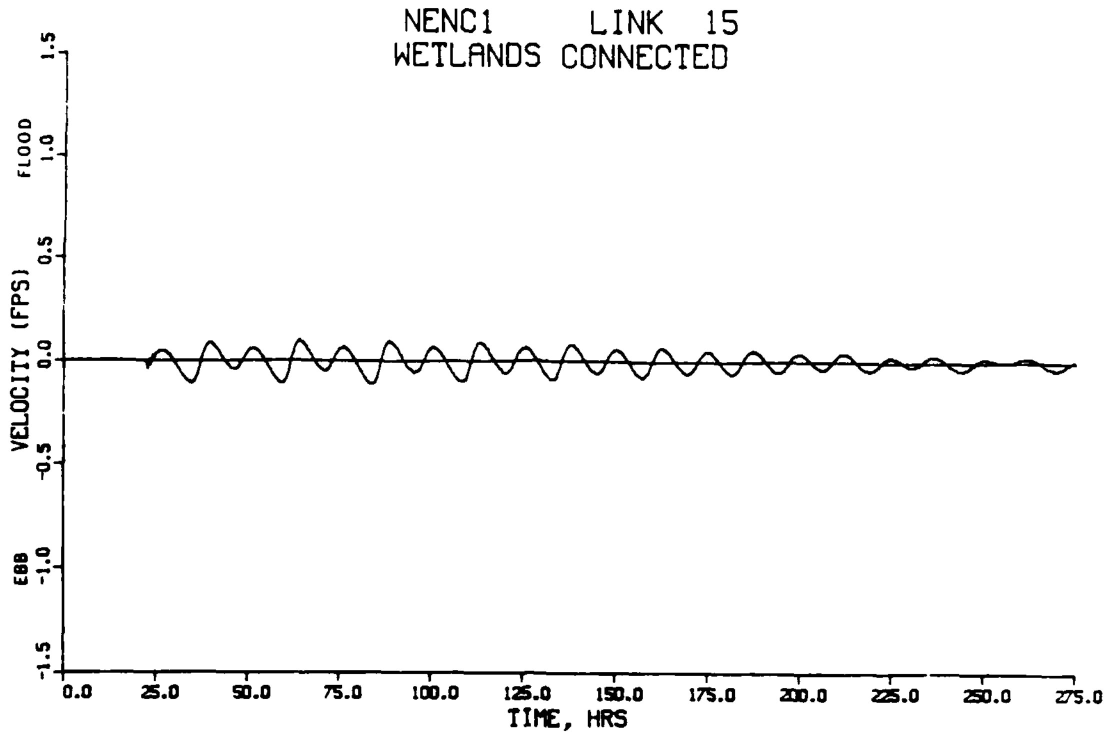


Figure D9. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

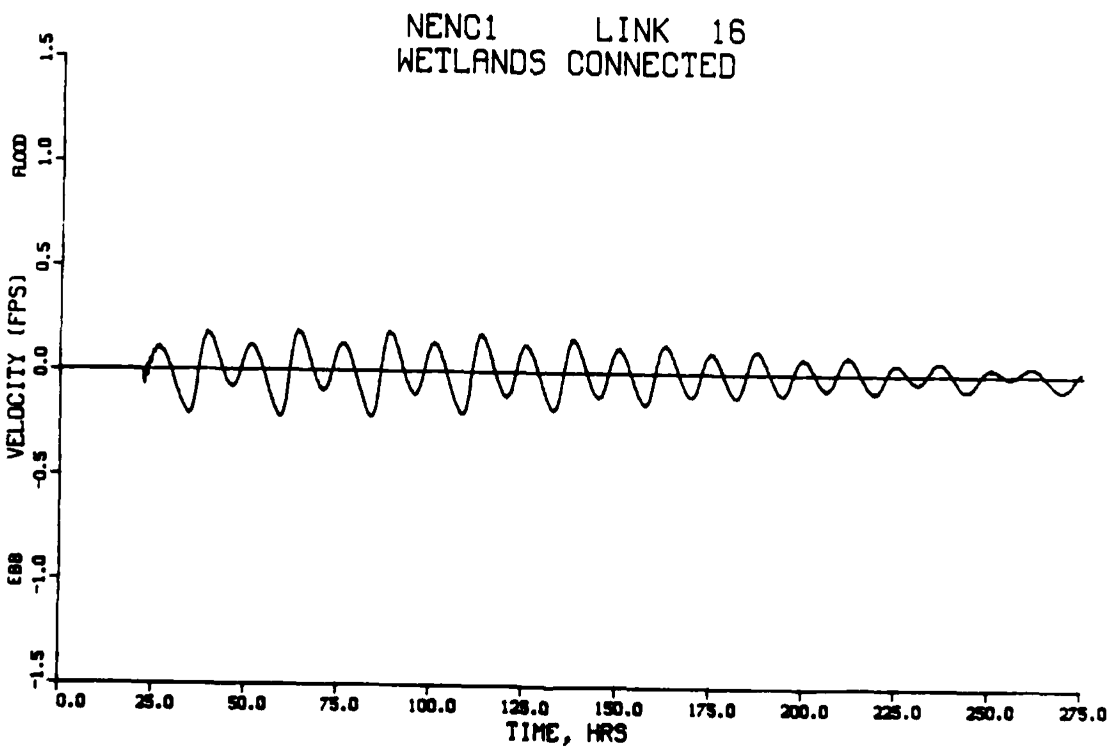


Figure D10. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

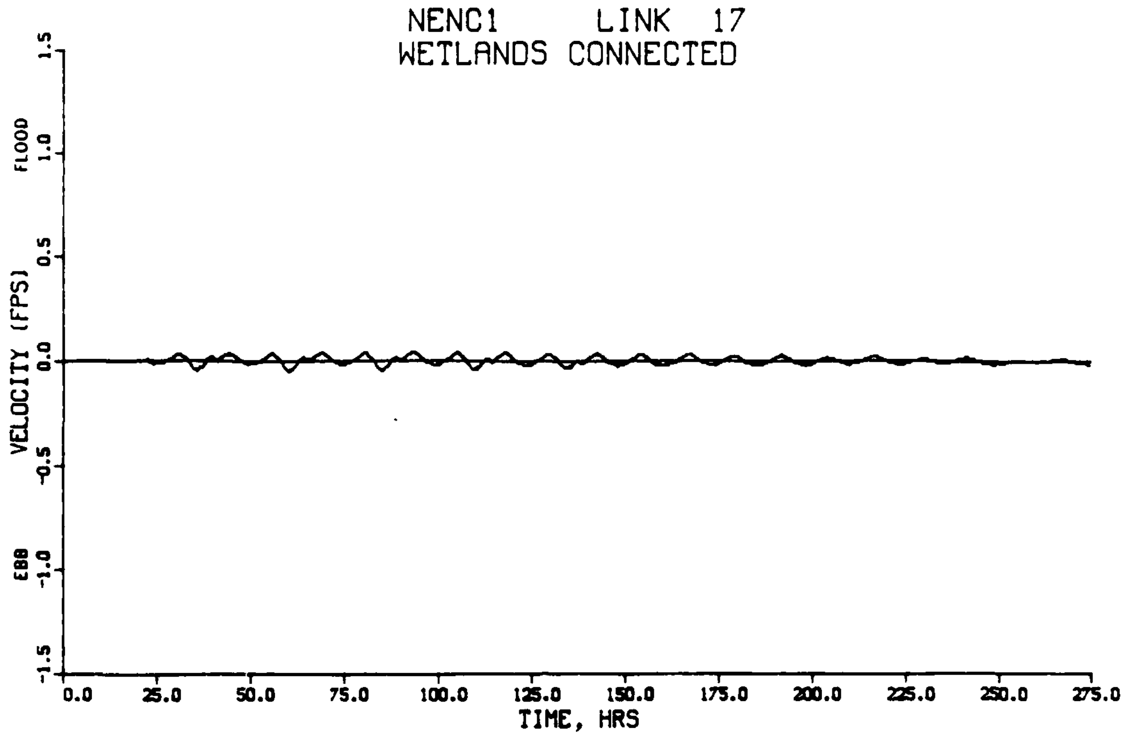


Figure D11. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

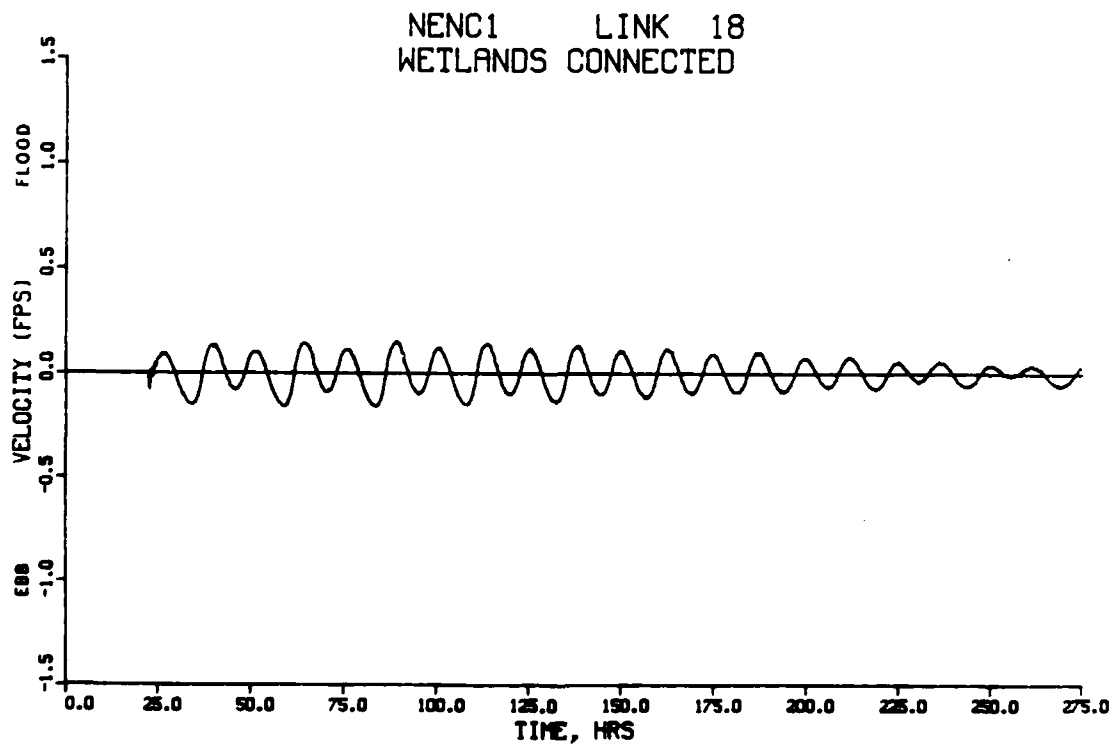


Figure D12. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

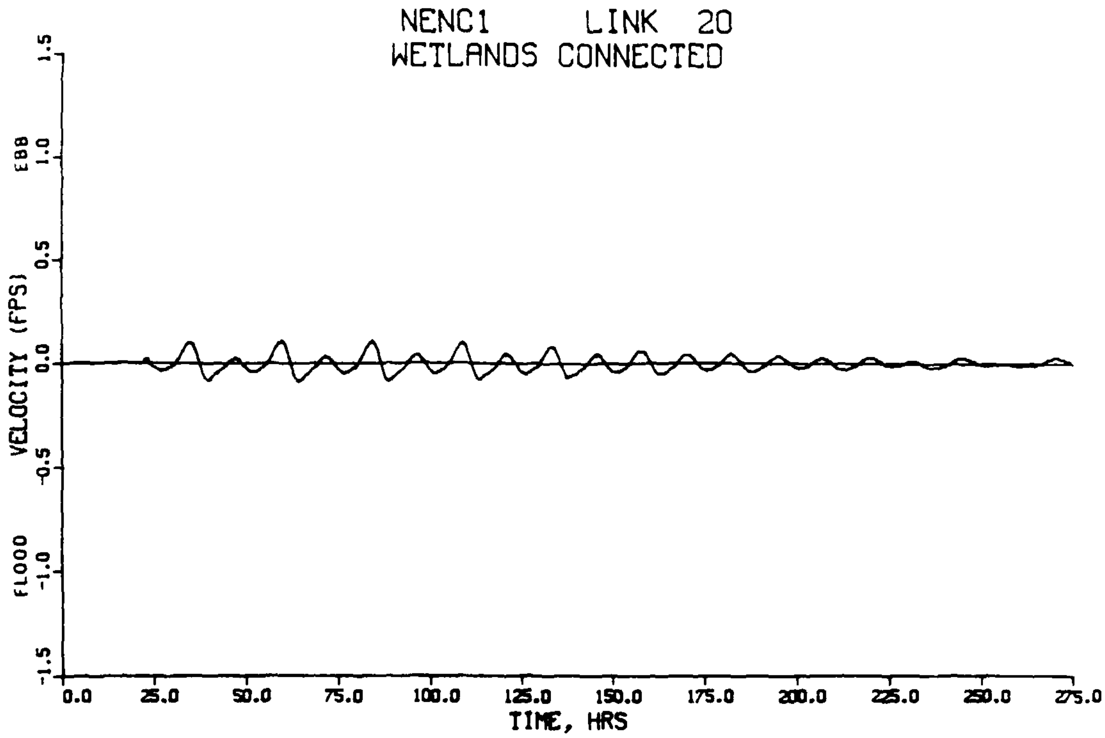


Figure D13. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

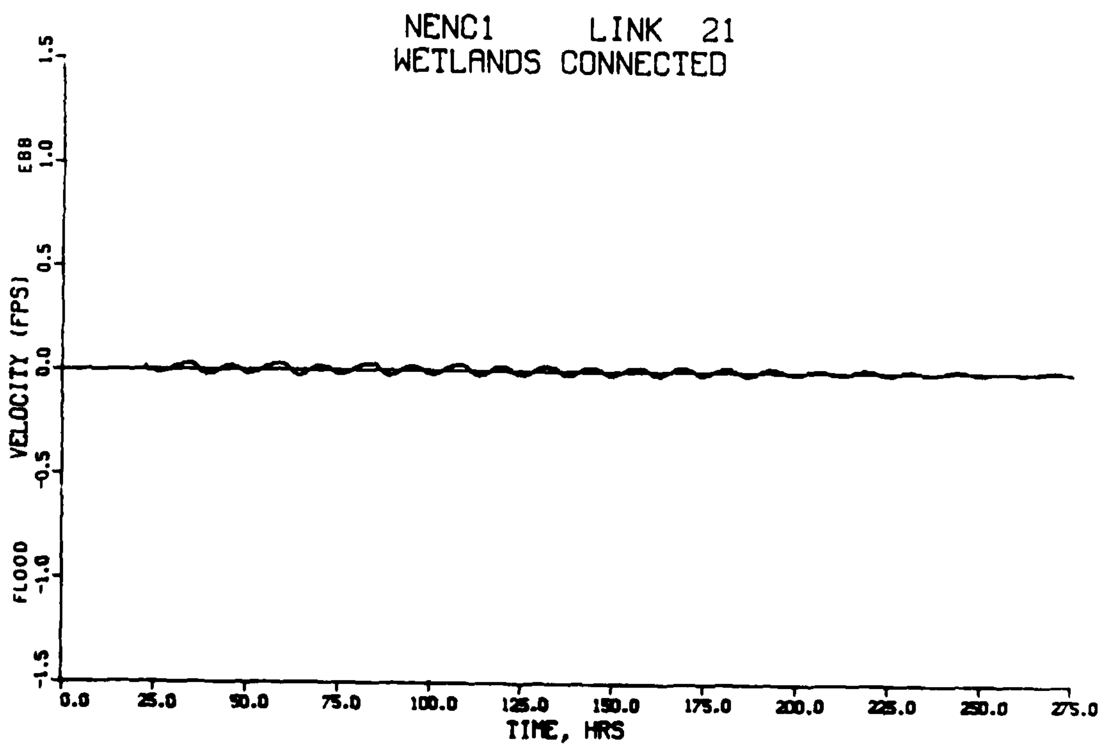


Figure D14. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

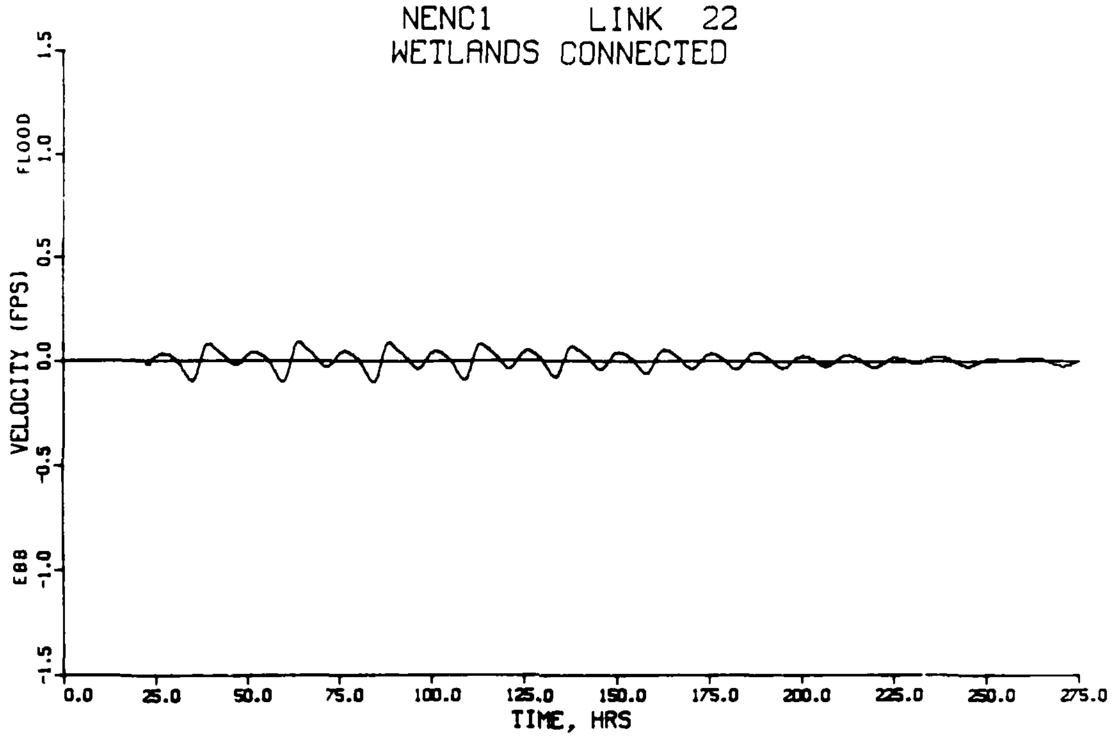


Figure D15. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

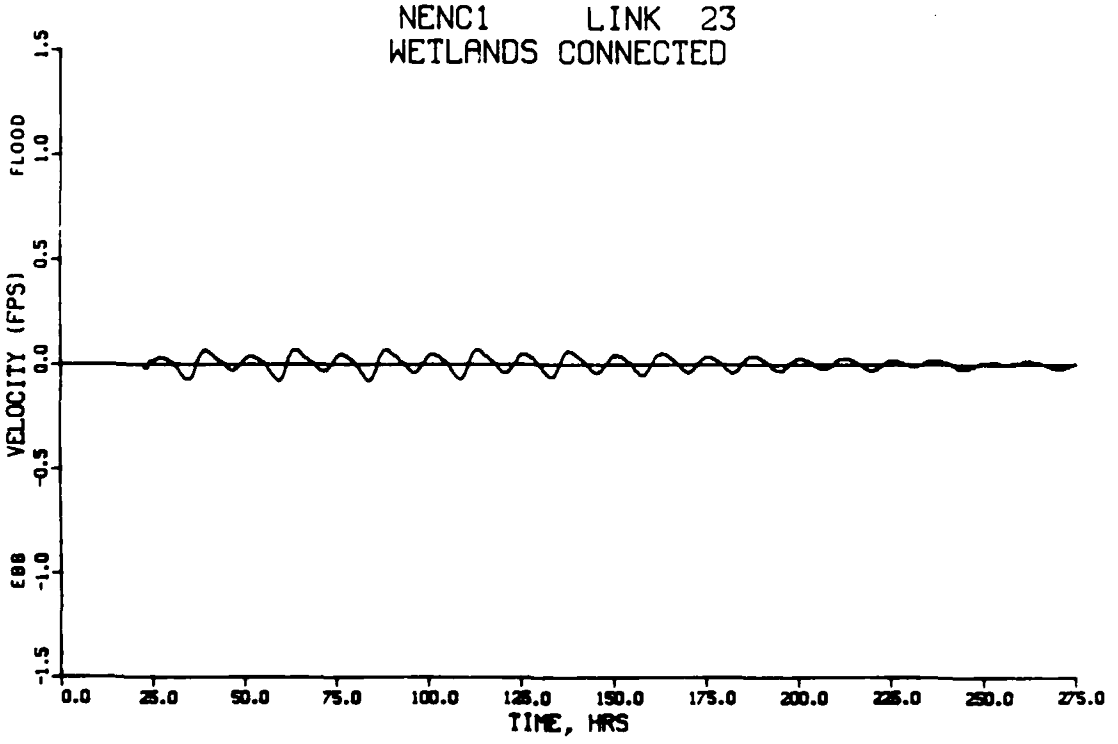


Figure D16. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

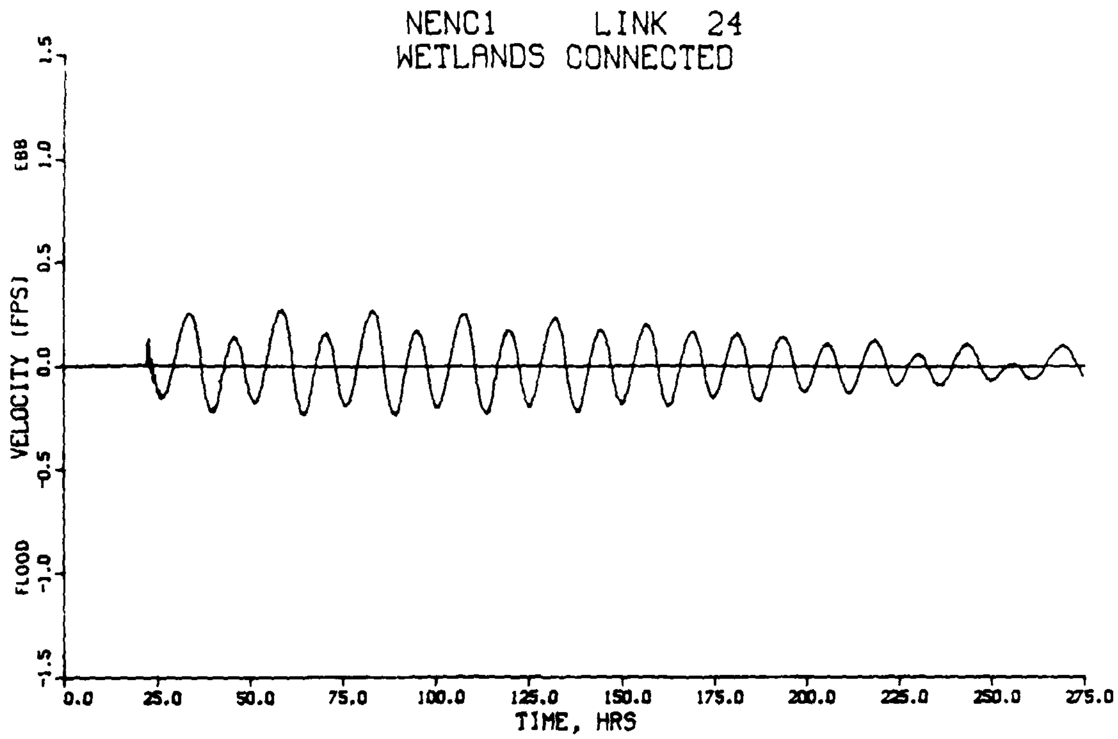


Figure D17. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

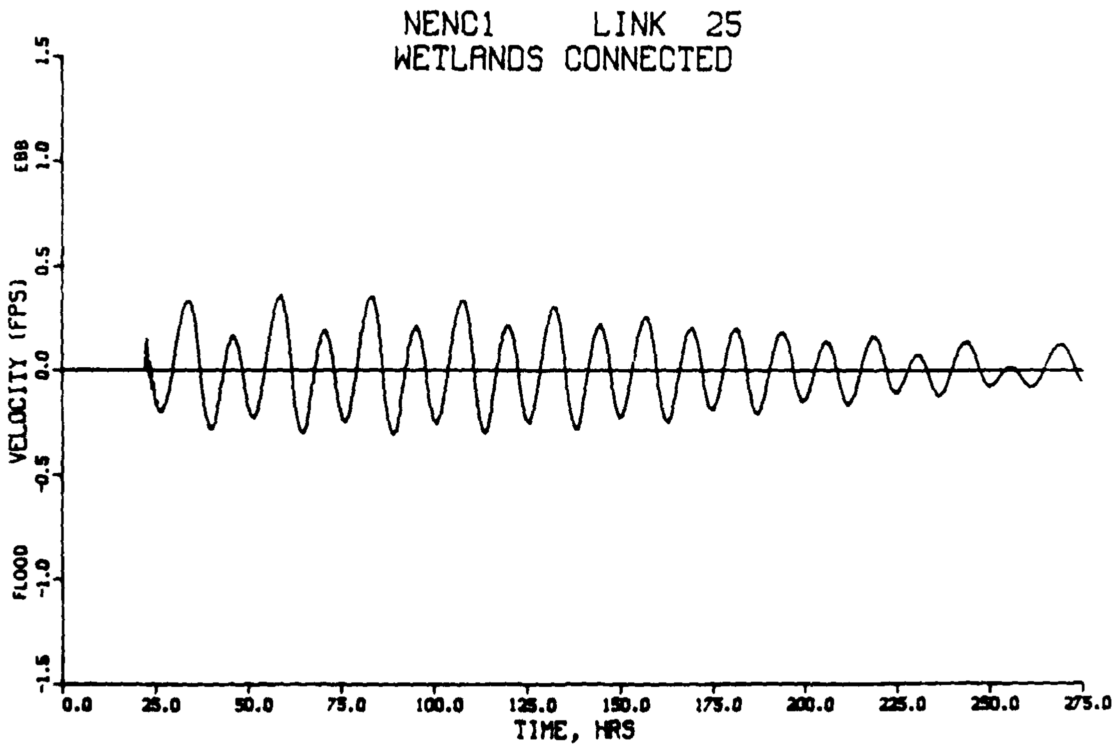


Figure D18. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

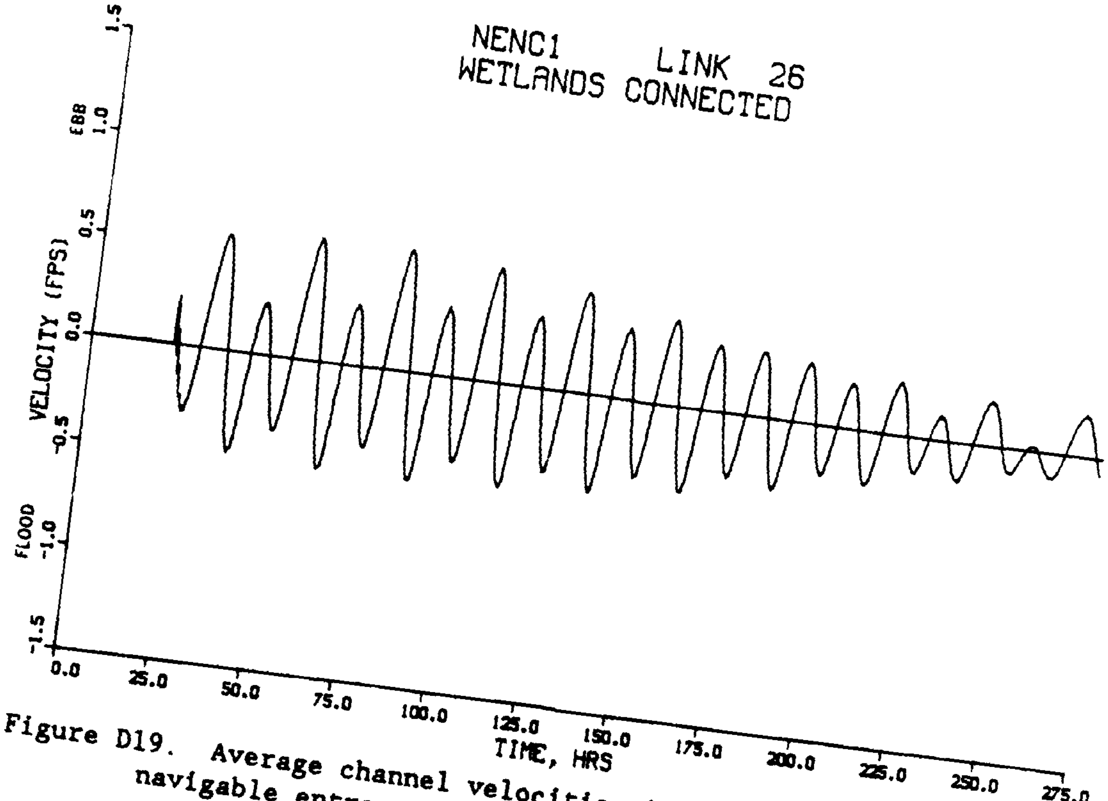


Figure D19. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

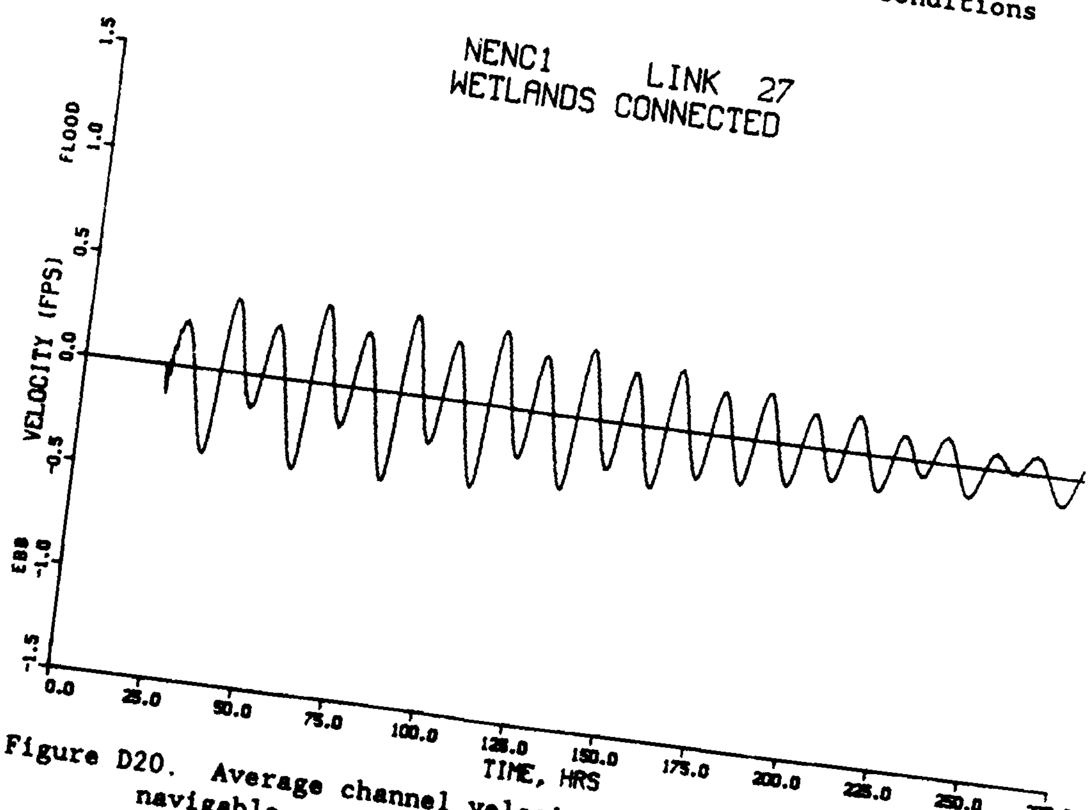


Figure D20. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

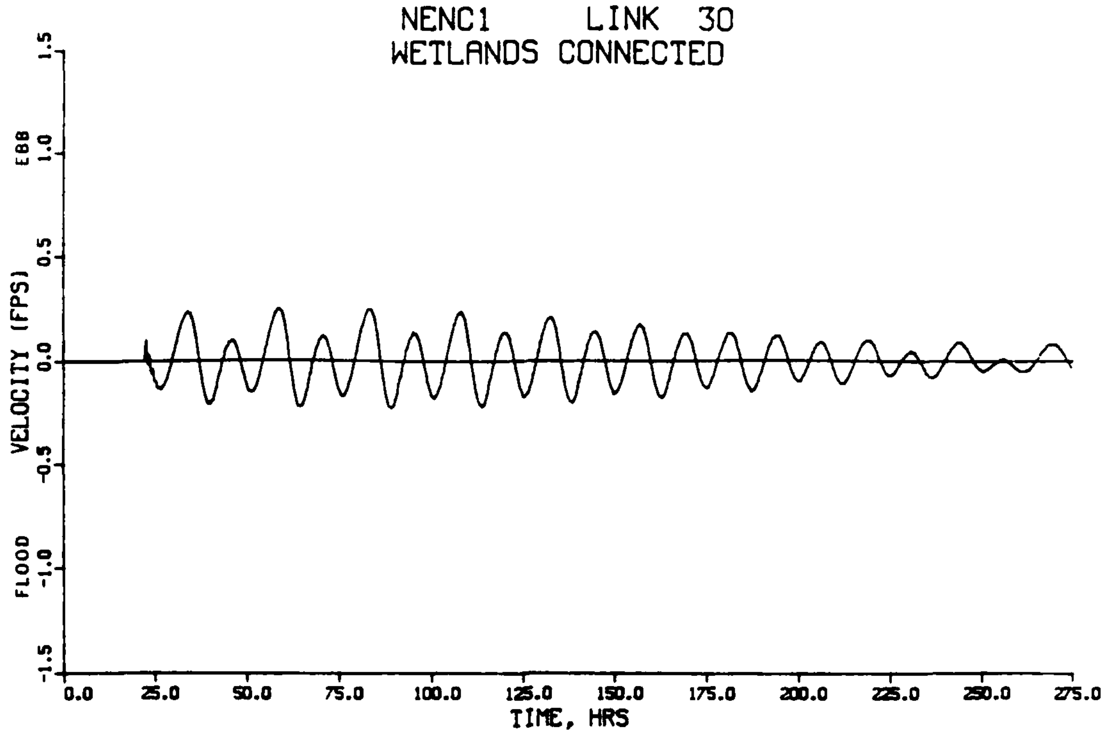


Figure D21. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

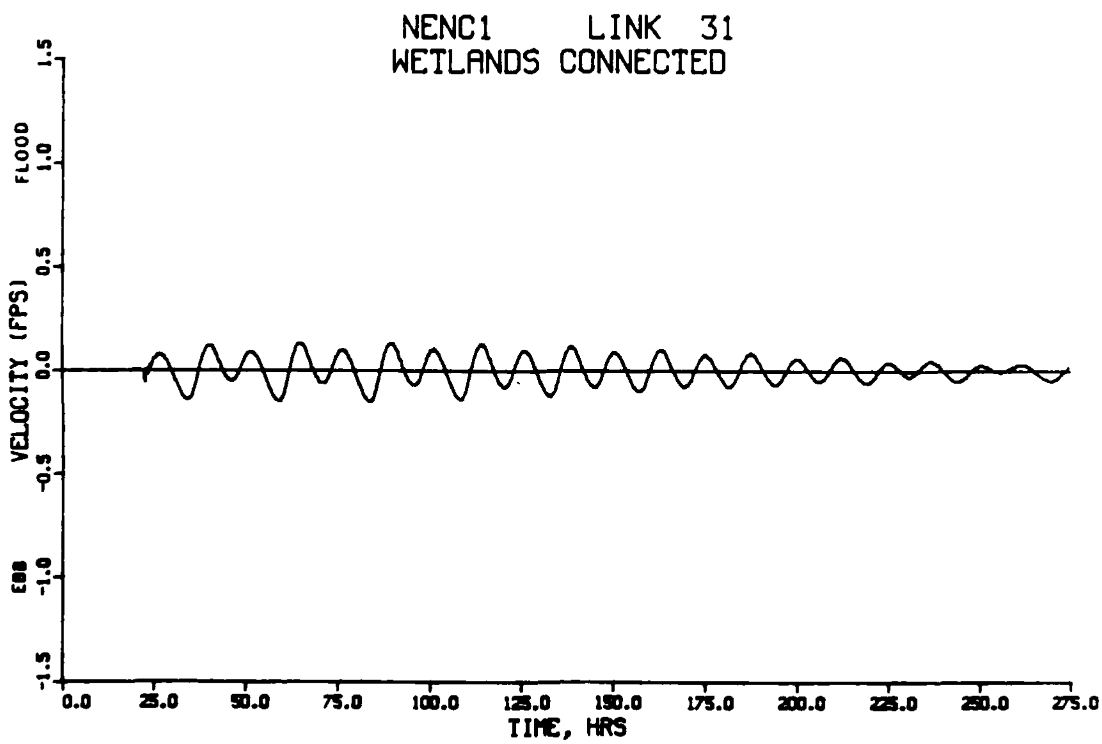


Figure D22. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

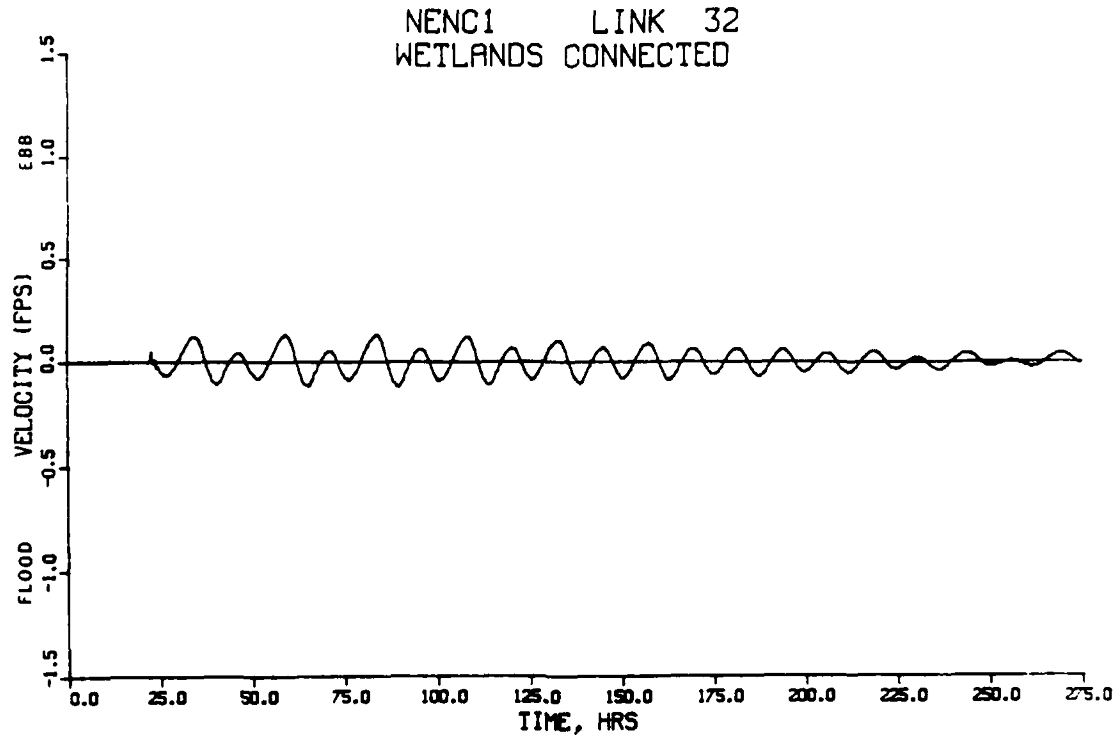


Figure D23. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

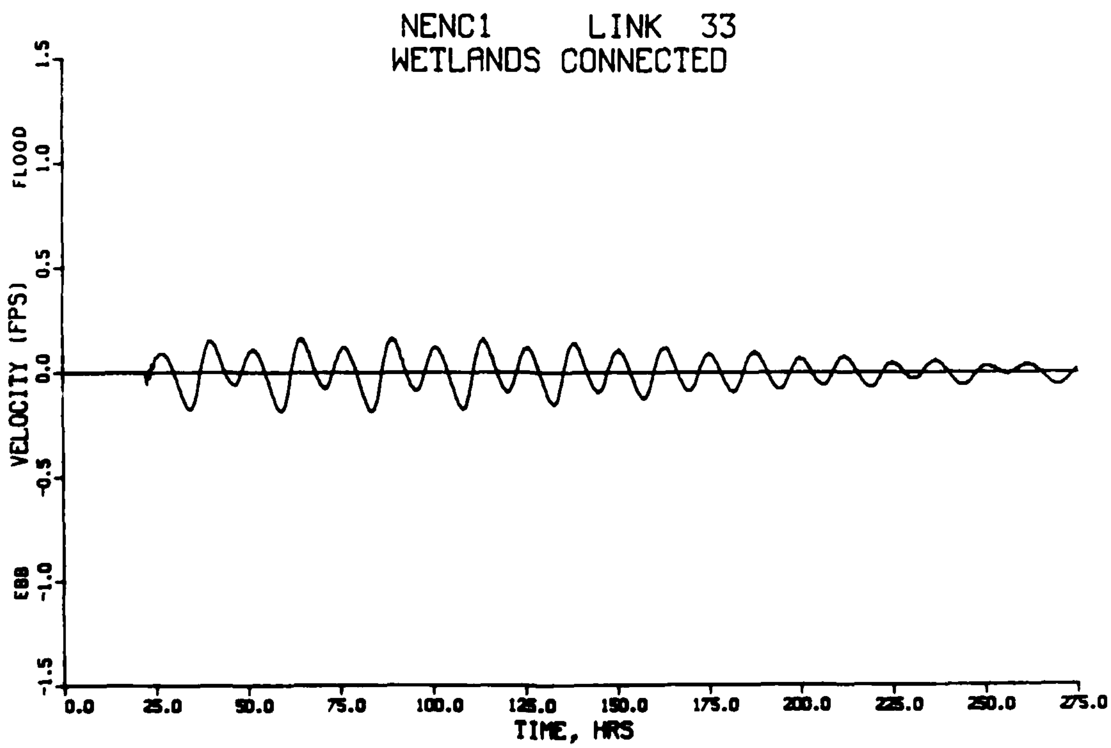


Figure D24. Average channel velocities in Huntington Harbour under navigable entrance, navigable connector conditions

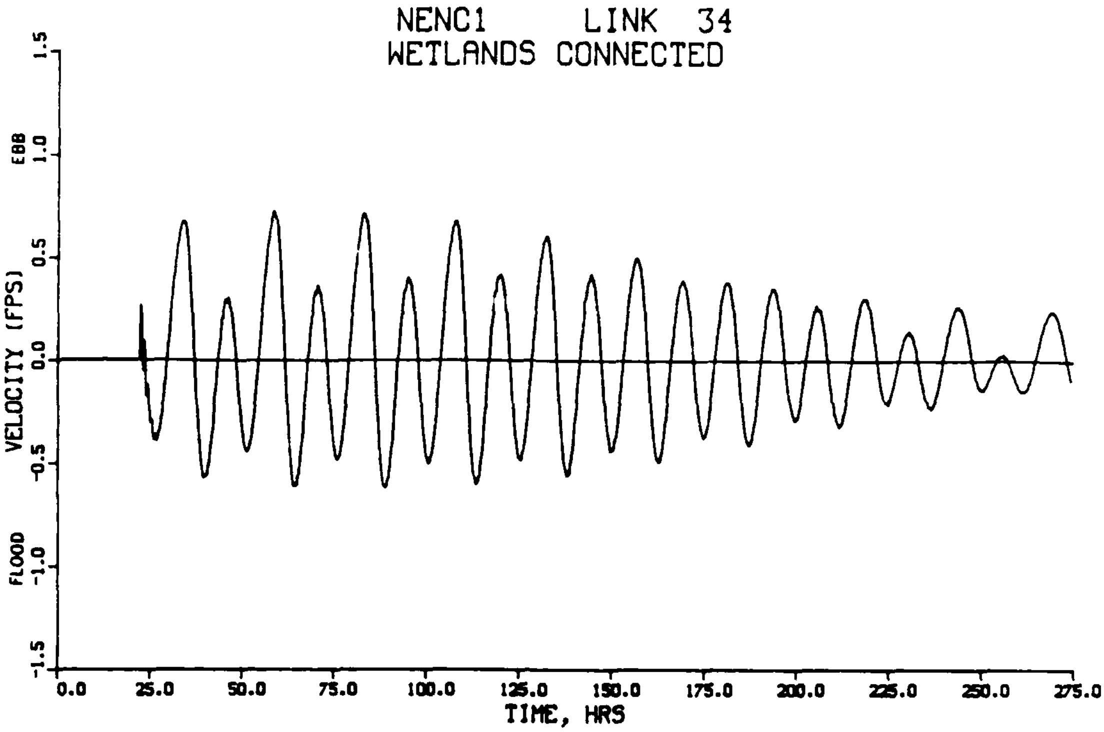


Figure D25. Average channel velocities at Warner Avenue under navigable entrance, navigable connector conditions

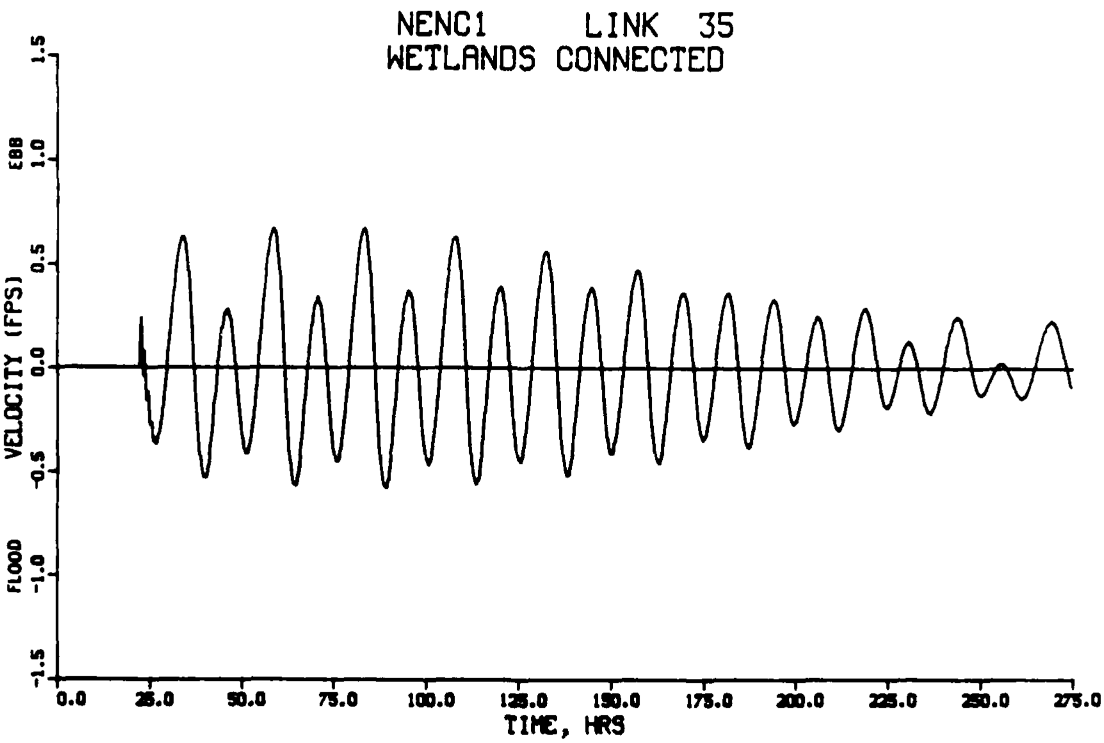


Figure D26. Average channel velocities in Outer Bolsa Bay under navigable entrance, navigable connector conditions

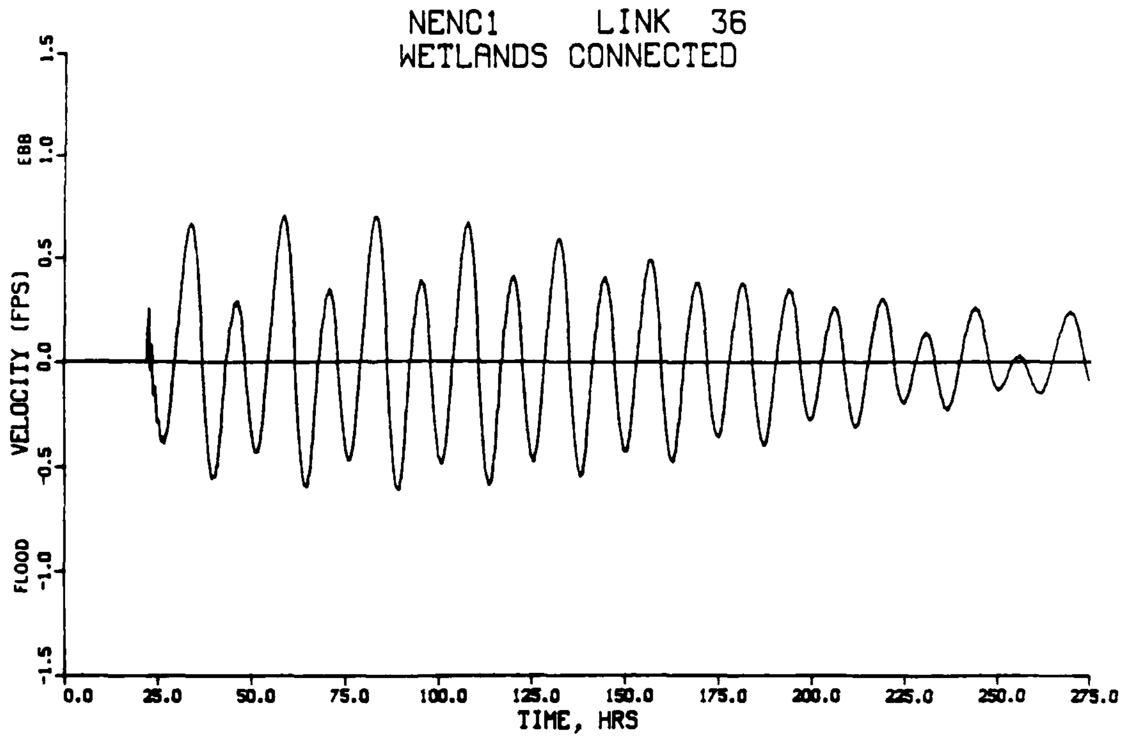


Figure D27. Average channel velocities in Outer Bolsa Bay under navigable entrance, navigable connector conditions

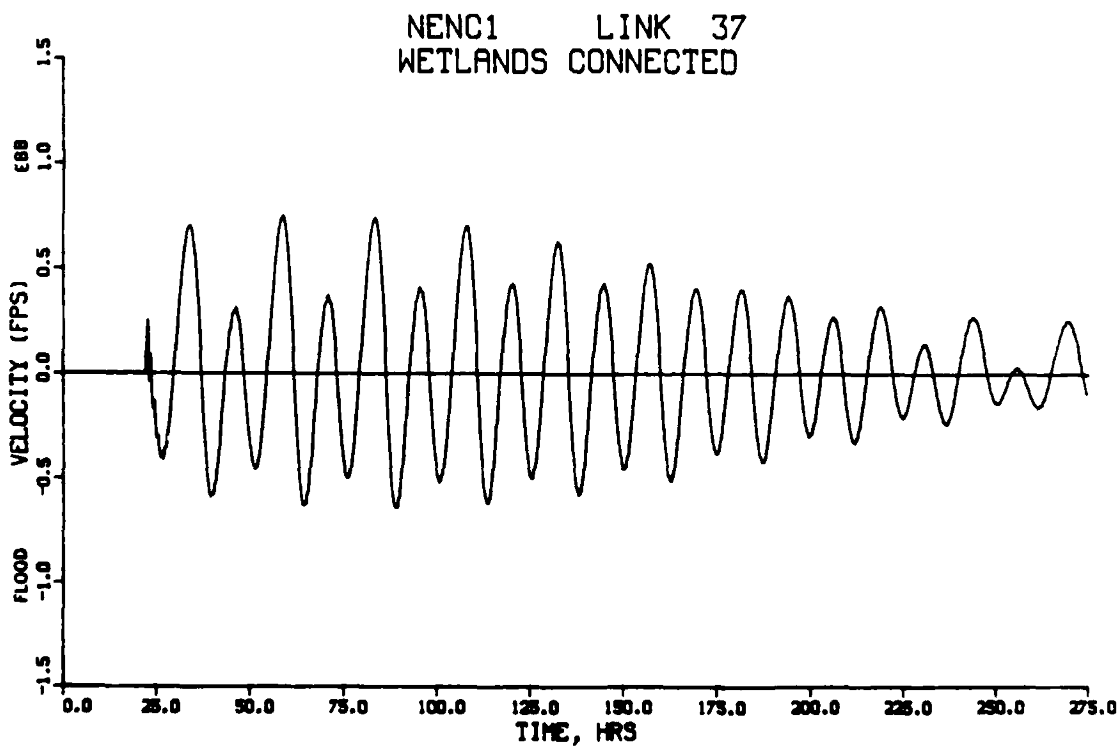


Figure D28. Average channel velocities in Outer Bolsa Bay under navigable entrance, navigable connector conditions

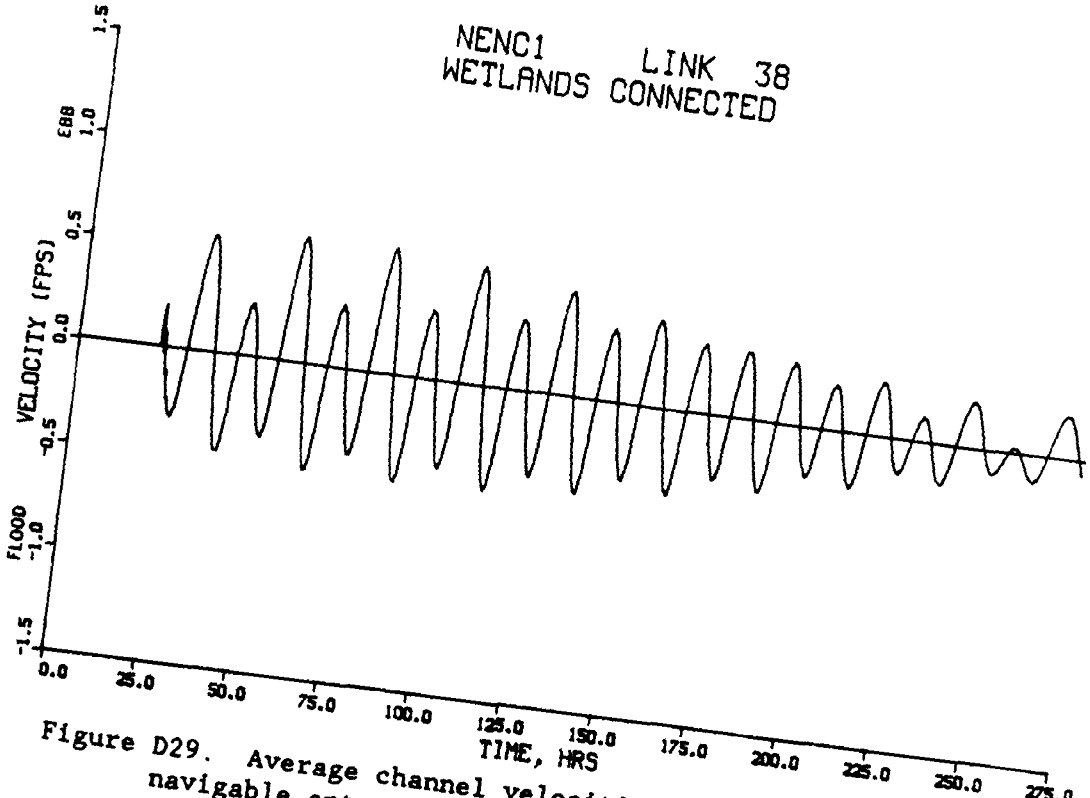


Figure D29. Average channel velocities in Outer Bolsa Bay under navigable entrance, navigable connector conditions

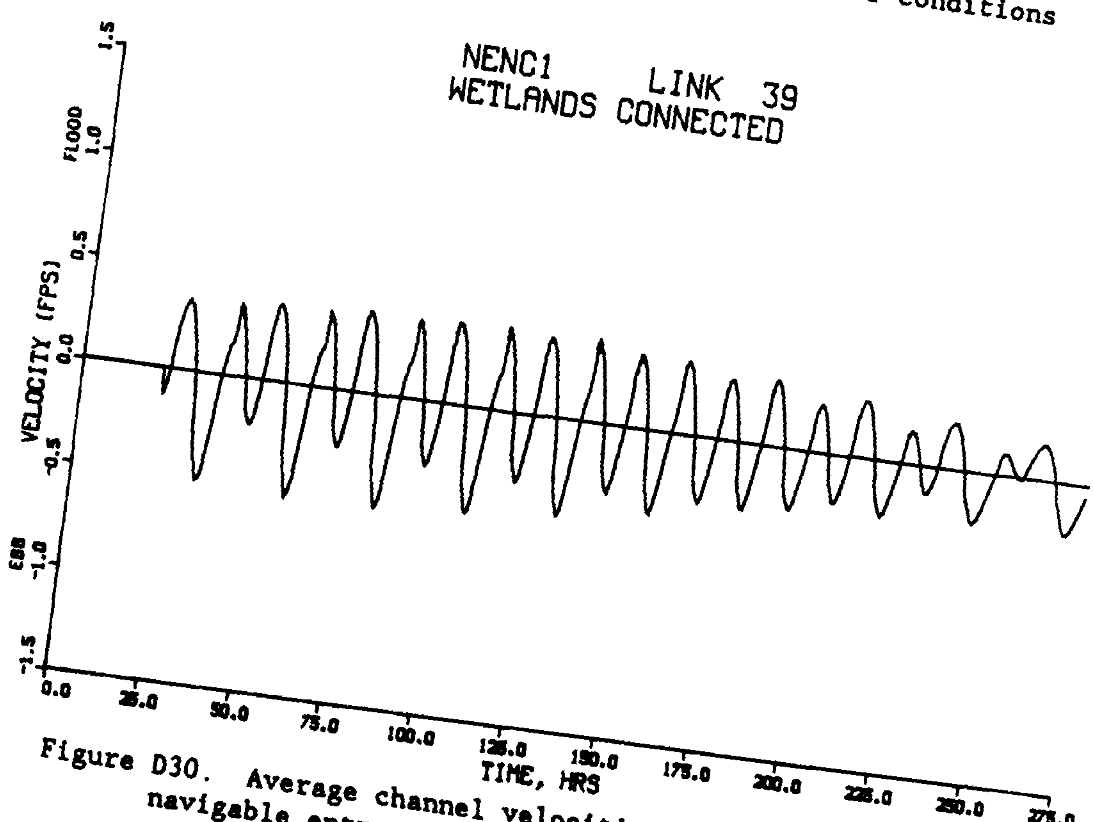


Figure D30. Average channel velocities in proposed marina under navigable entrance, navigable connector conditions

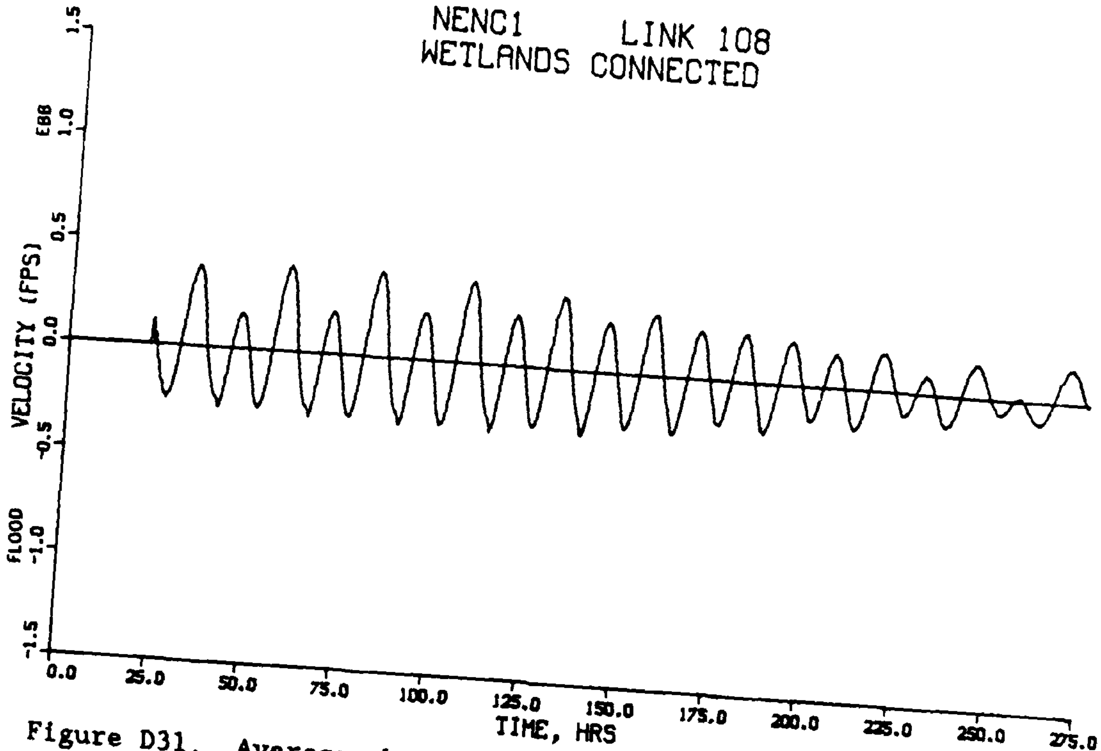


Figure D31. Average channel velocities in proposed entrance under navigable entrance, navigable connector conditions

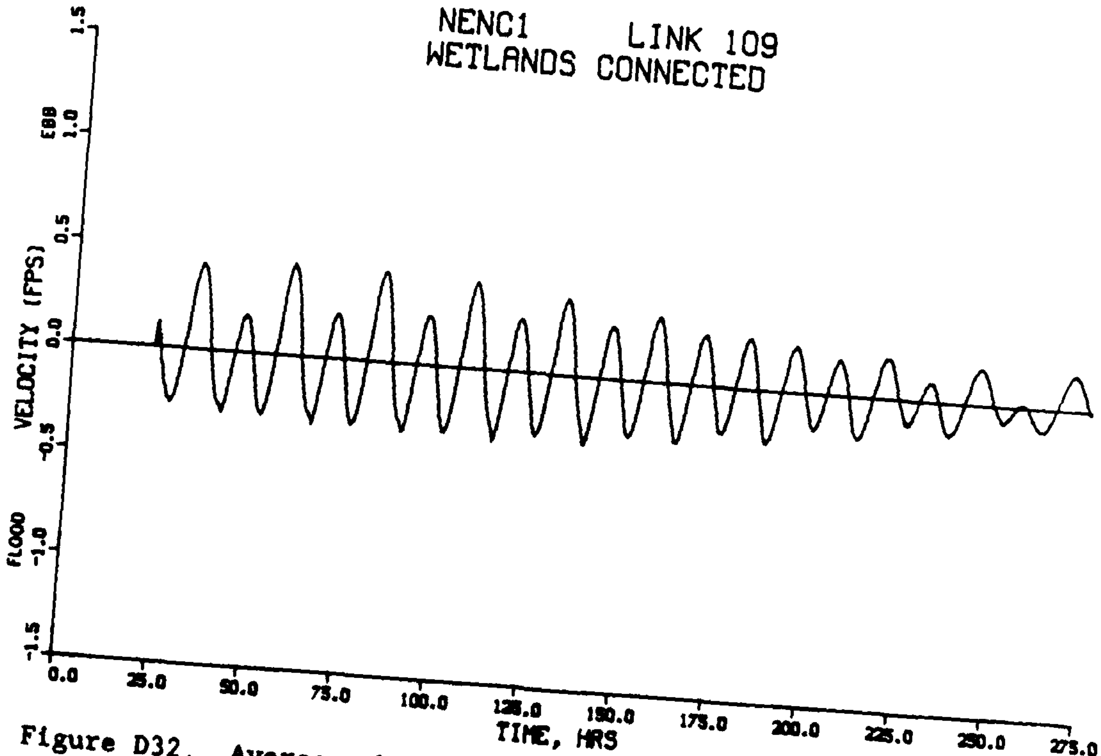


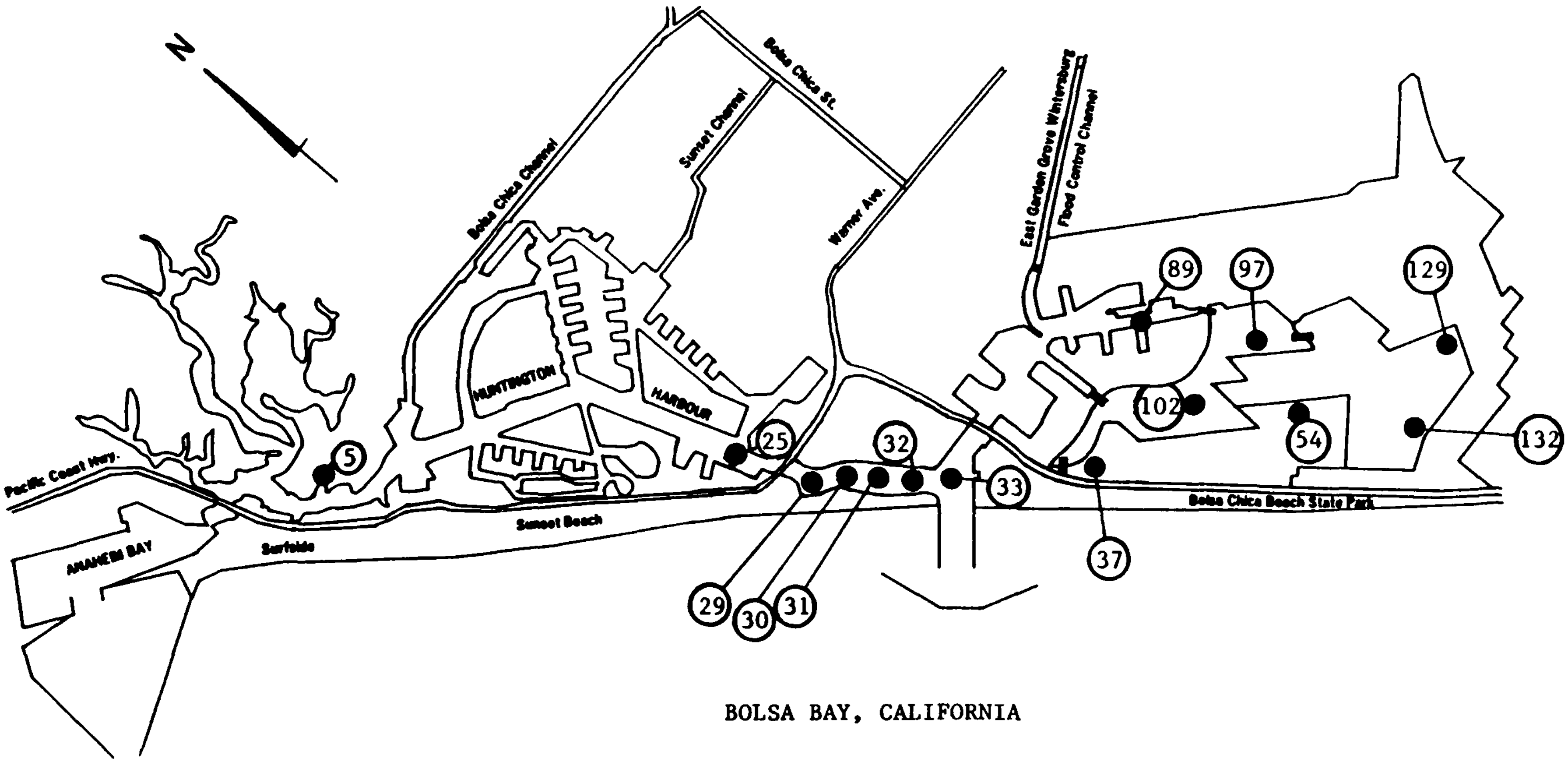
Figure D32. Average channel velocities in proposed entrance under navigable entrance, navigable connector conditions

APPENDIX E:

NENNC1

NAVIGABLE ENTRANCE CHANNEL
AND
NON-NAVIGABLE CONNECTOR CHANNEL TO HUNTINGTON HARBOUR

WATER SURFACE ELEVATIONS



BOLSA BAY, CALIFORNIA

NENNC1
Location of nodes for displaying water surface elevations
under navigable entrance channel and non-navigable connector channel to Huntington Harbour conditions

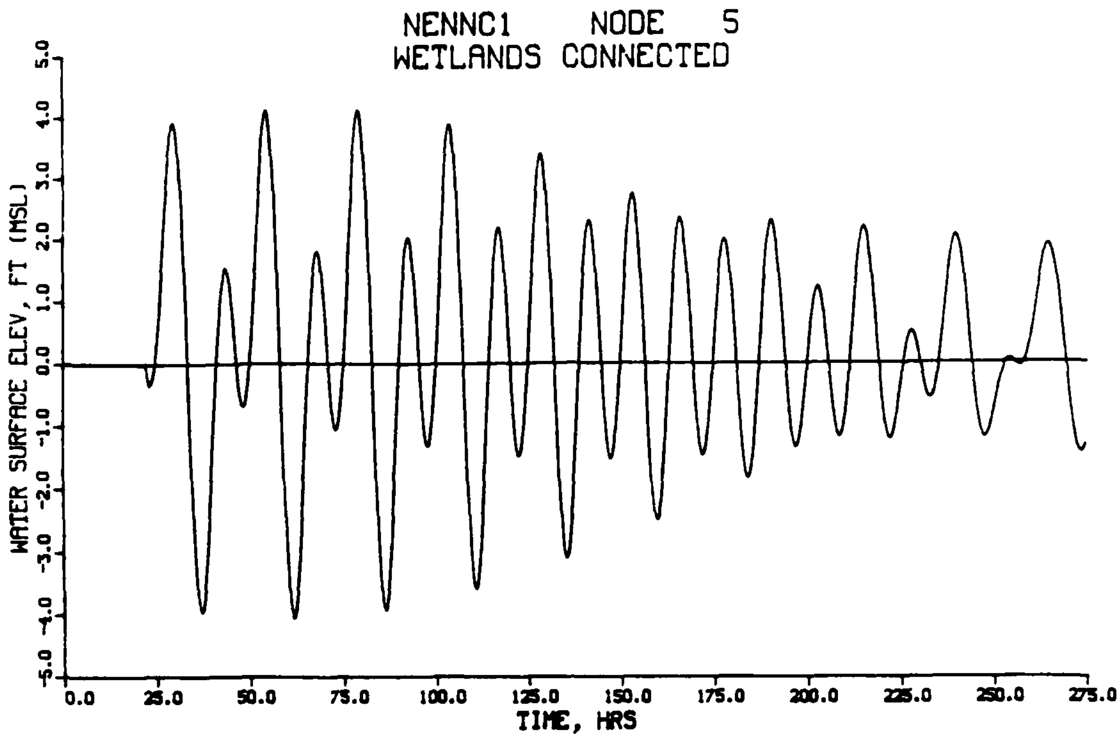


Figure E1. Tidal elevations in Huntington Harbour under navigable entrance, non-navigable connector conditions

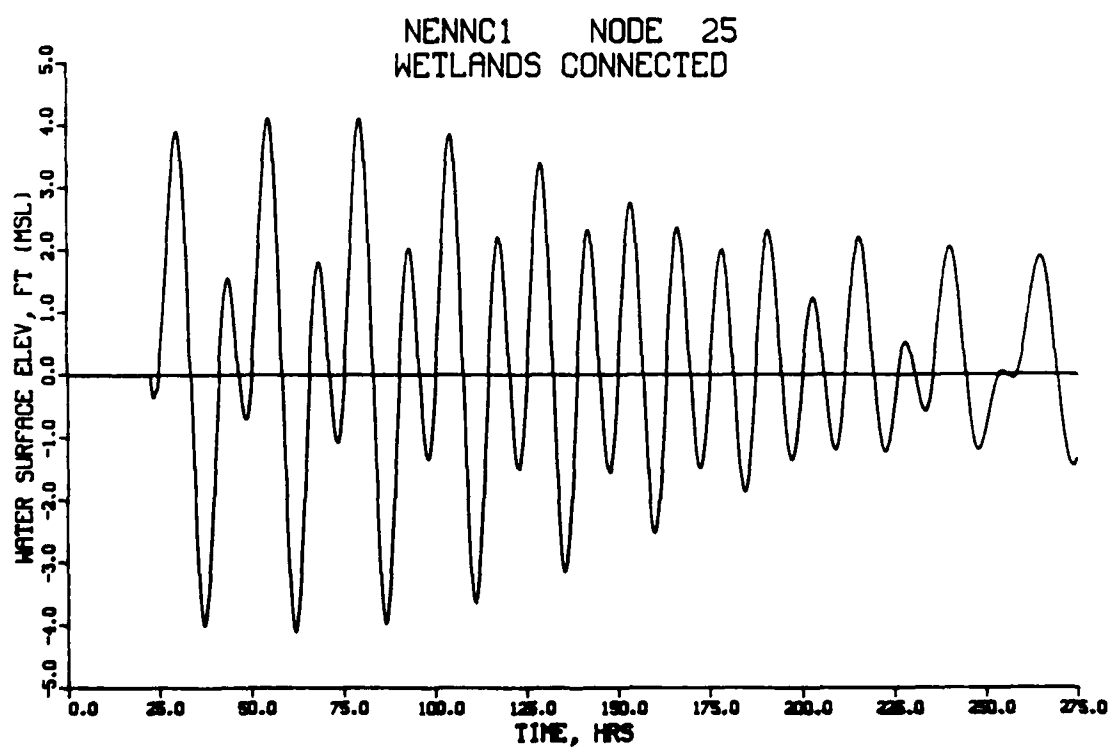


Figure E2. Tidal elevations in Huntington Harbour under navigable entrance, non-navigable connector conditions

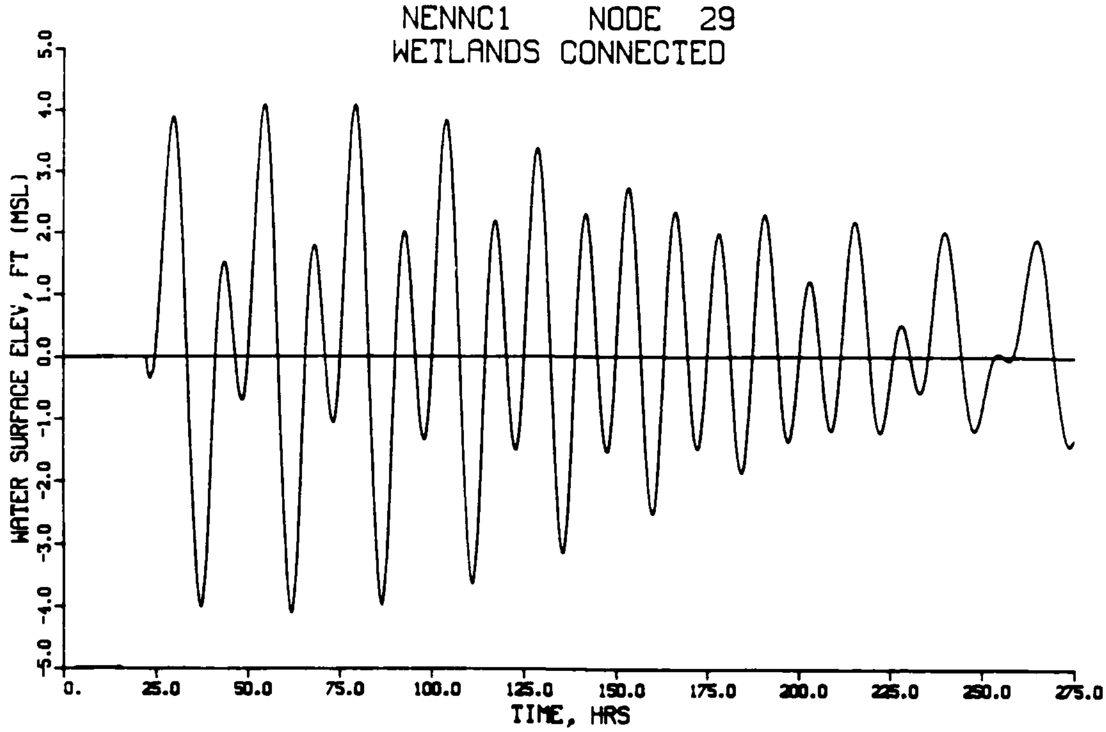


Figure E3. Tidal elevations in Outer Bolsa Bay under navigable entrance, non-navigable connector conditions

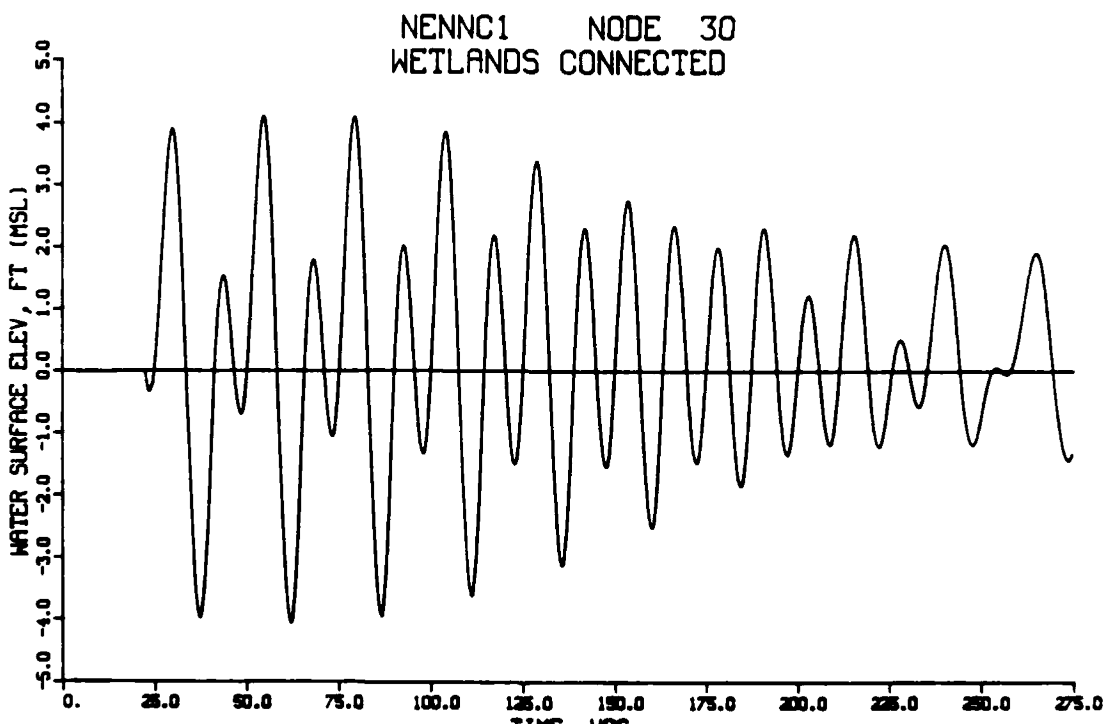


Figure E4. Tidal elevations in Outer Bolsa Bay under navigable entrance, non-navigable connector conditions

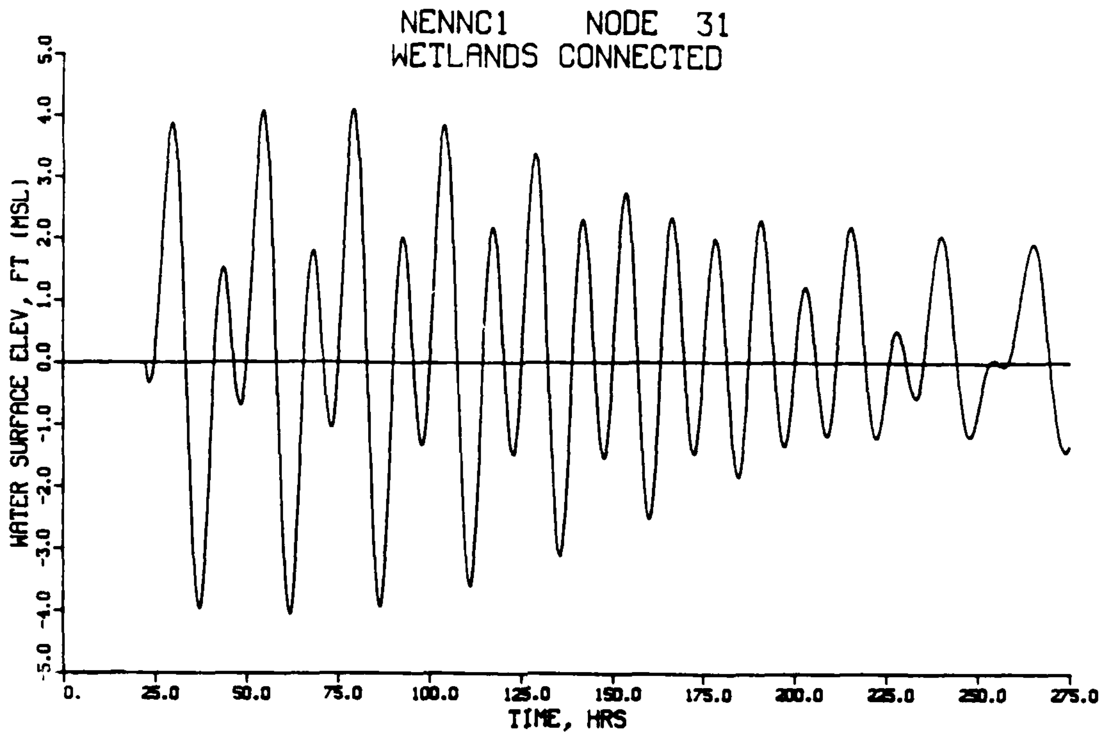


Figure E5. Tidal elevations in Outer Bolsa Bay under navigable entrance, non-navigable connector conditions

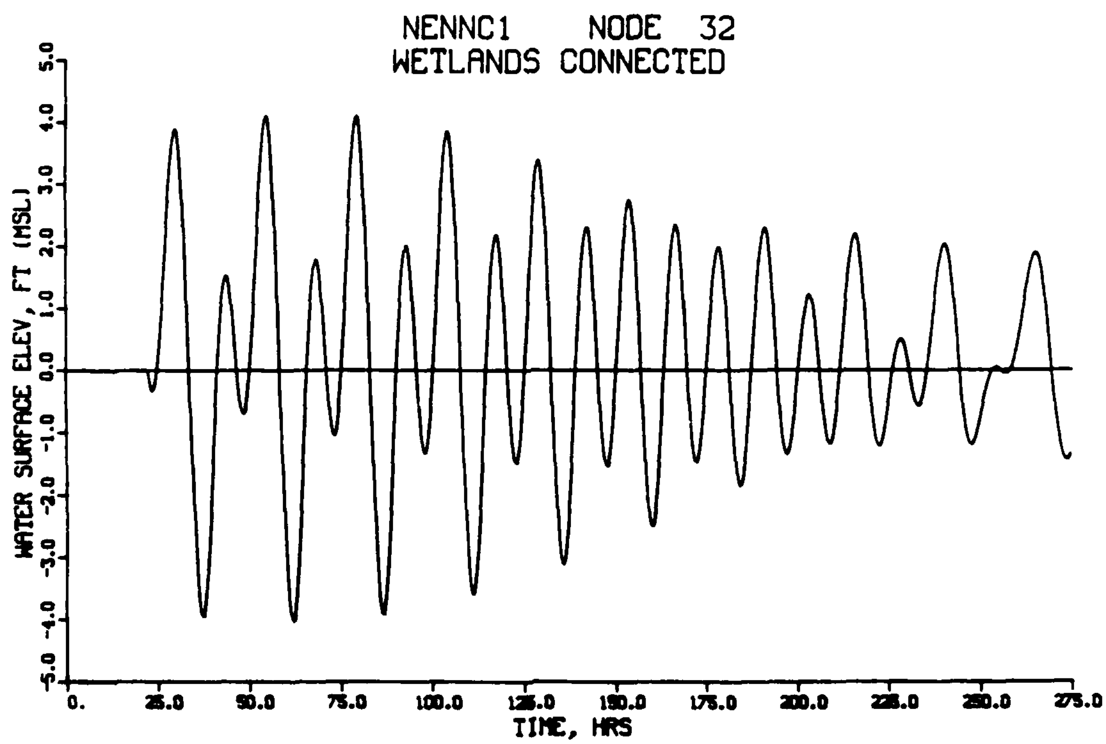


Figure E6. Tidal elevations in Outer Bolsa Bay under navigable entrance, non-navigable connector conditions

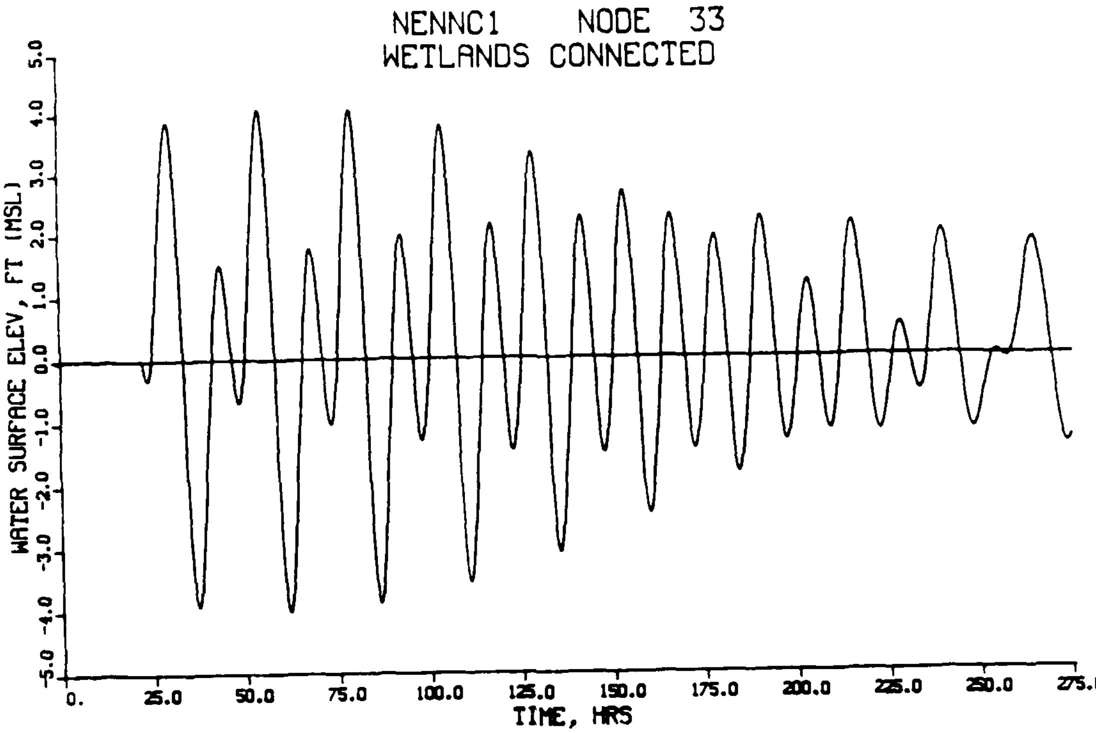


Figure E7. Tidal elevations in entrance channel under navigable entrance, non-navigable connector conditions

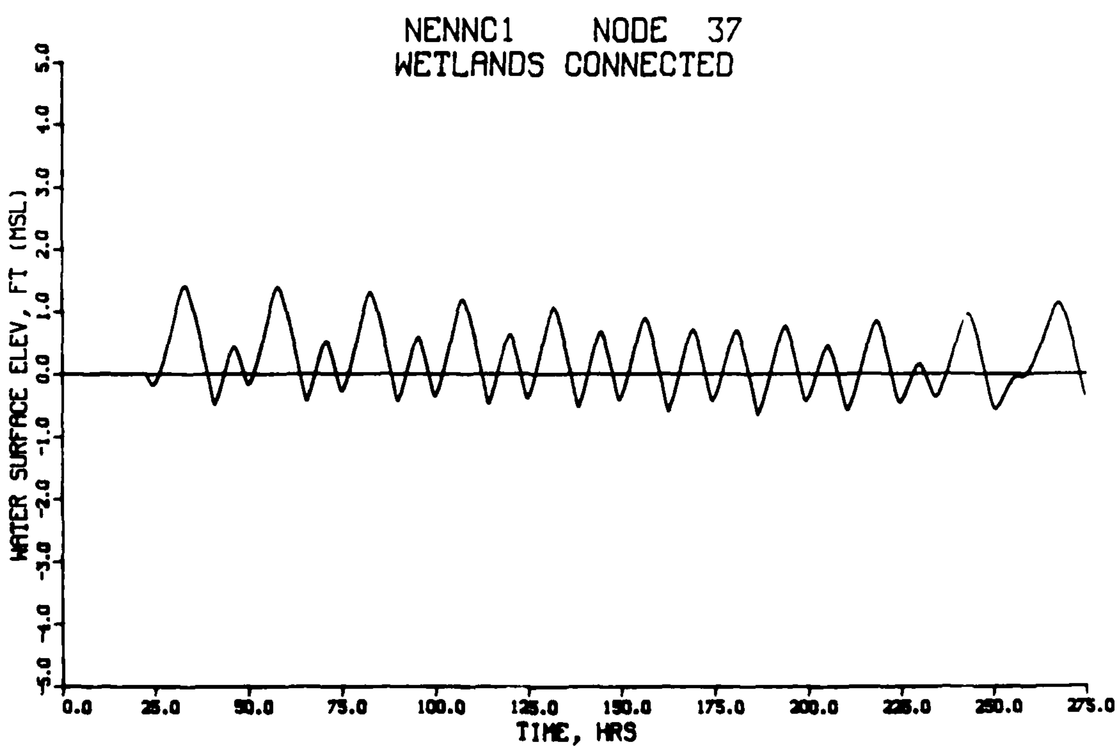


Figure E8. Tidal elevations in Inner Bolsa Bay under navigable entrance, non-navigable connector conditions

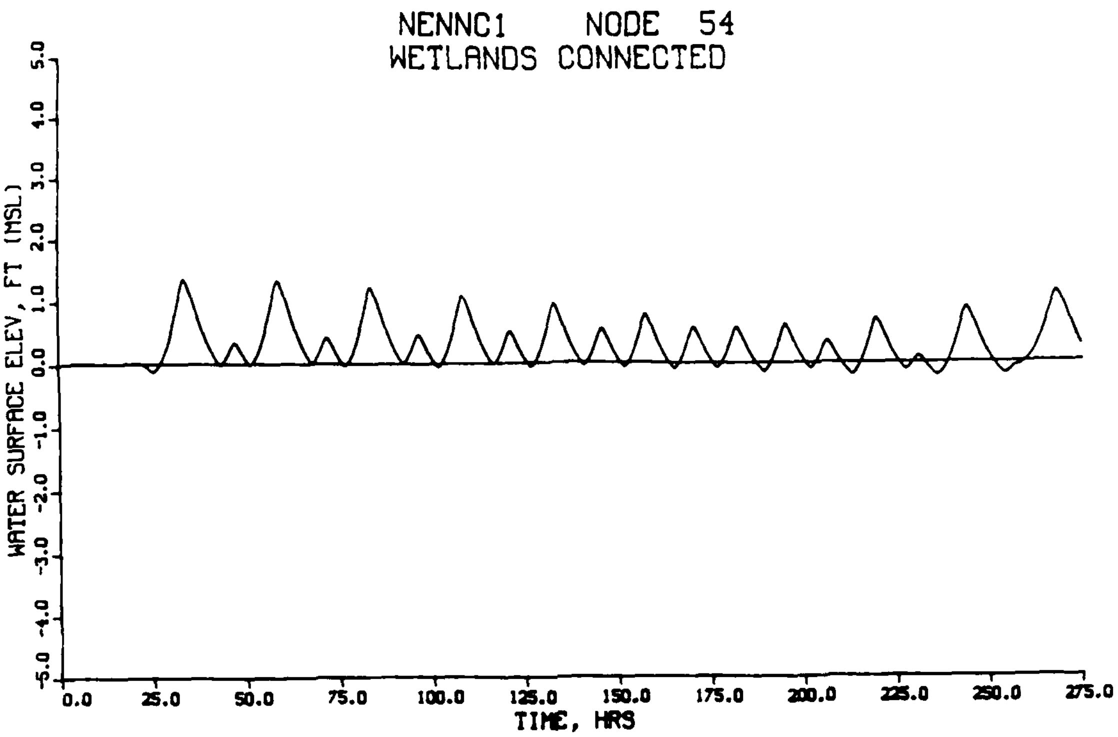


Figure E9. Tidal elevations in DFG muted tidal cell under navigable entrance, non-navigable connector conditions

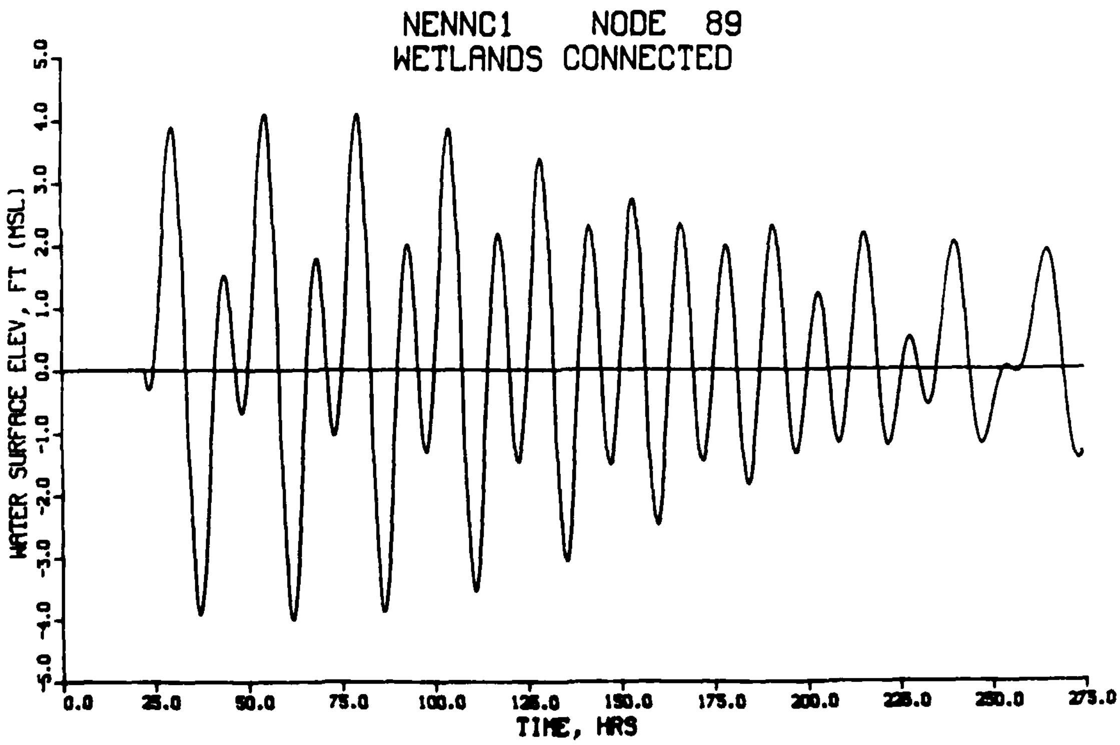


Figure E10. Tidal elevations in proposed marina channel under navigable entrance, non-navigable connector conditions

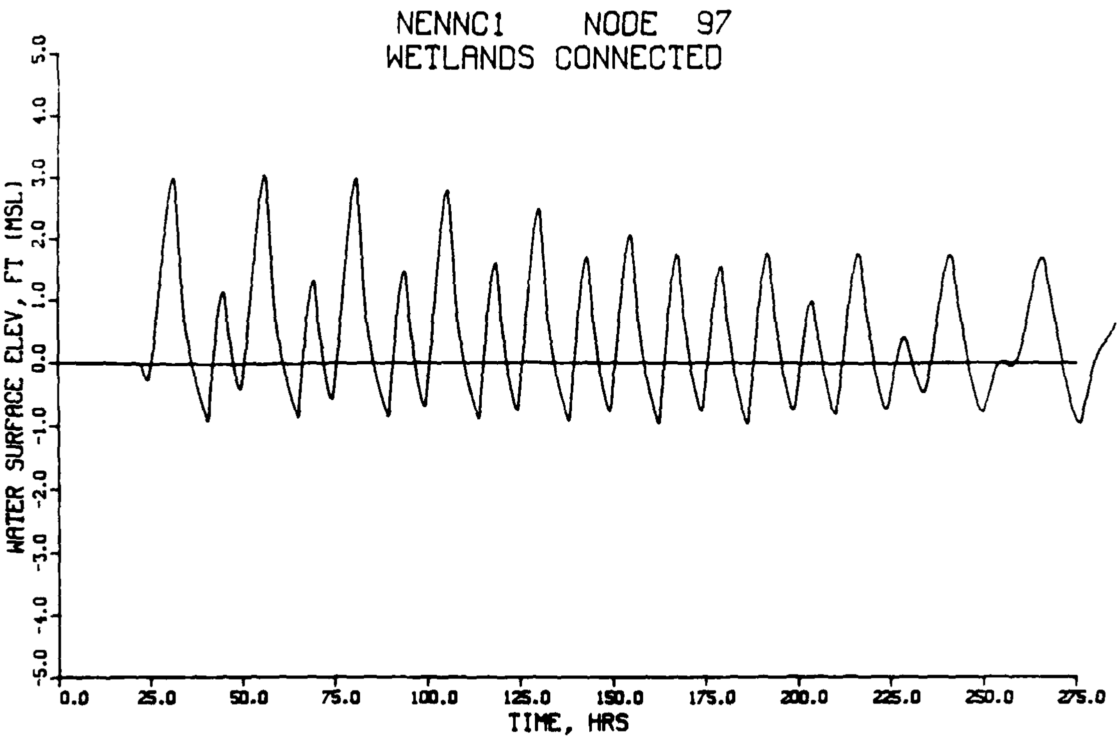


Figure E11. Tidal elevations in proposed full tidal wetlands under navigable entrance, non-navigable connector conditions

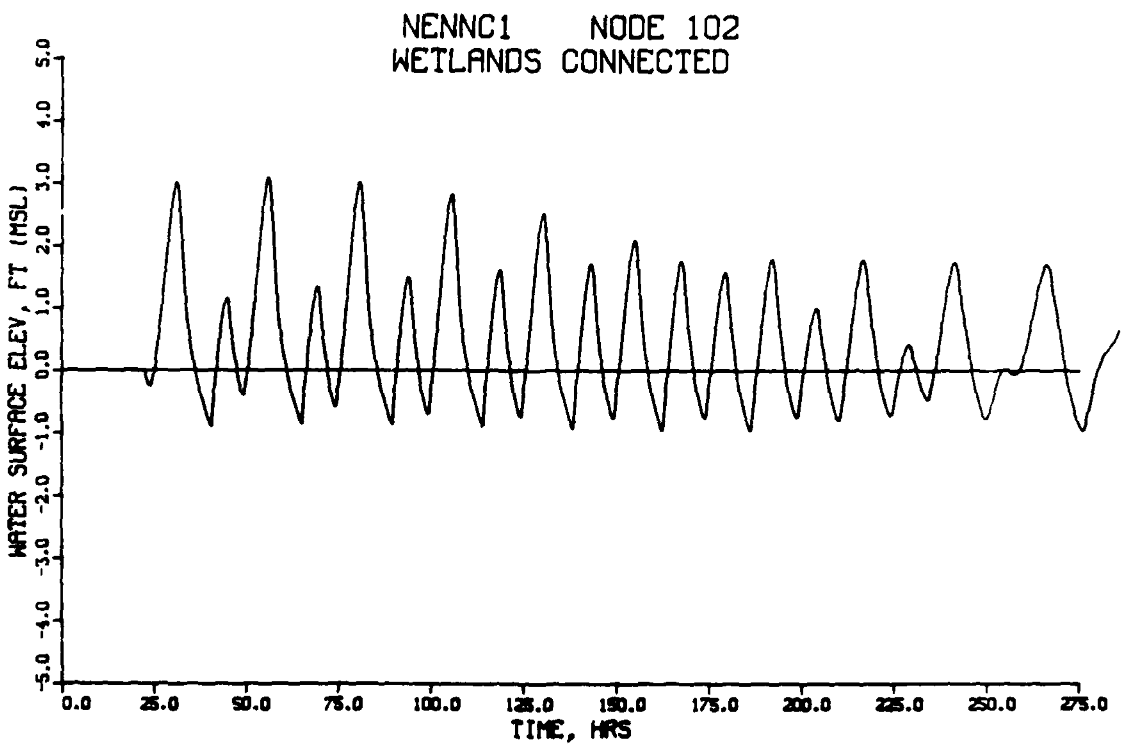


Figure E12. Tidal elevations in proposed full tidal wetlands under navigable entrance, non-navigable connector conditions

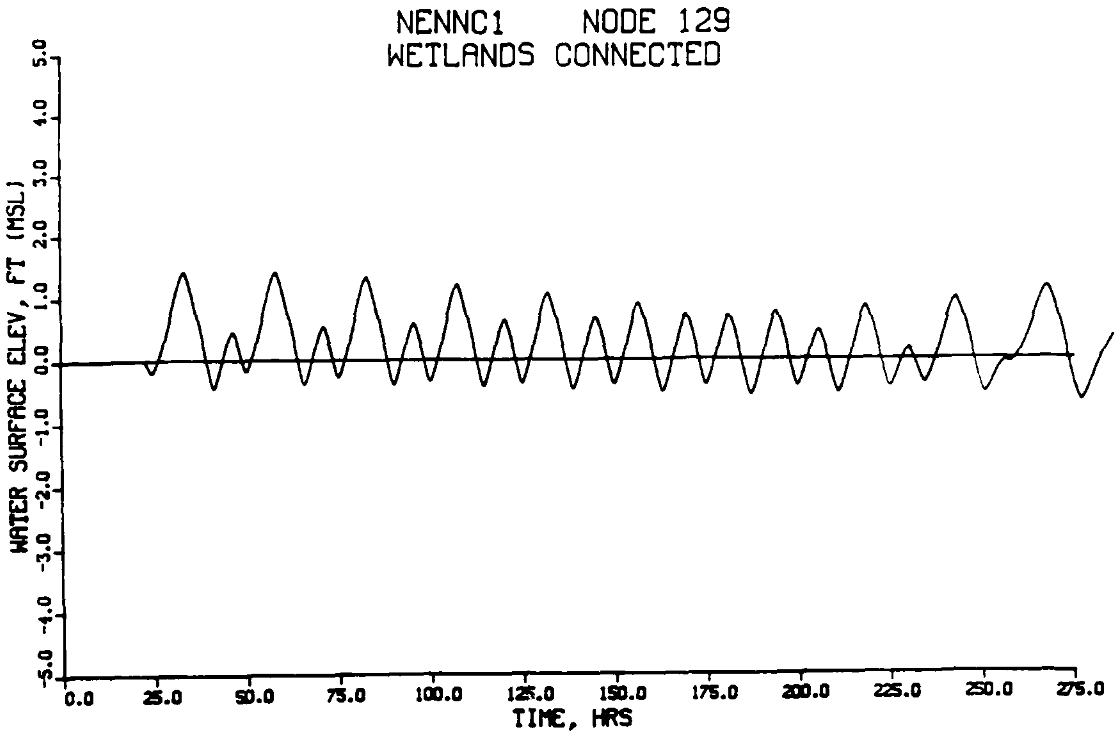


Figure E13. Tidal elevations in proposed muted tidal wetlands under navigable entrance, non-navigable connector conditions

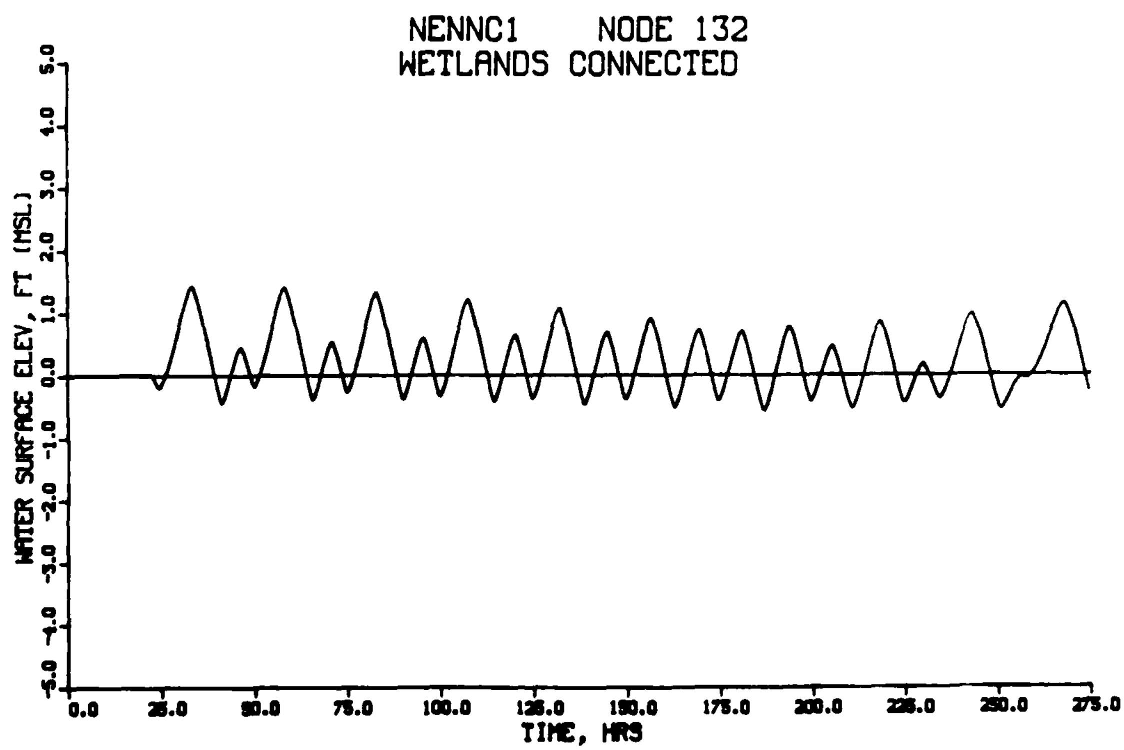


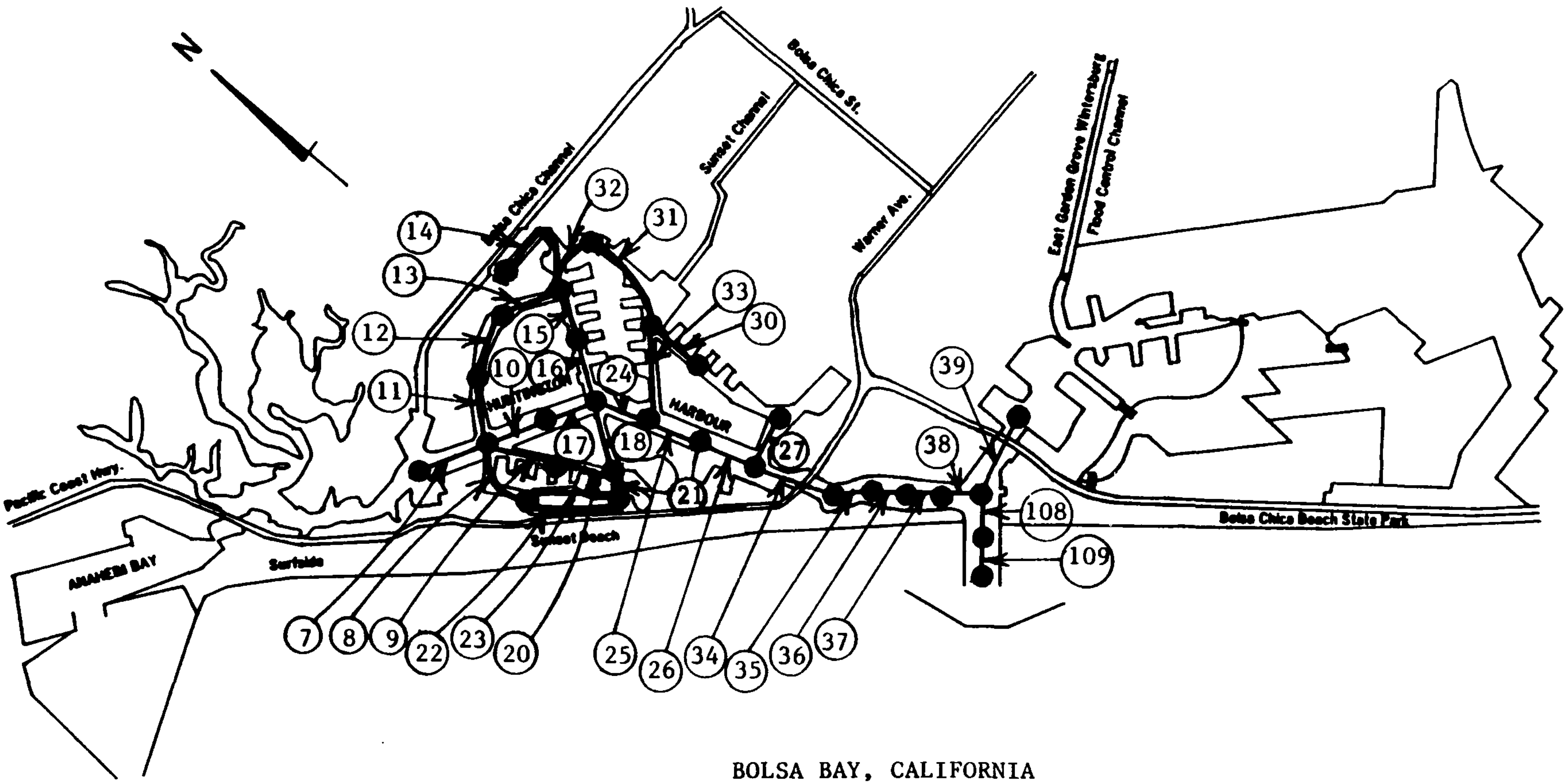
Figure E14. Tidal elevations in proposed muted tidal wetlands under navigable entrance, non-navigable connector conditions

APPENDIX F:

NENNC1

NAVIGABLE ENTRANCE CHANNEL
AND
NON-NAVIGABLE CONNECTOR CHANNEL TO HUNTINGTON HARBOUR

AVERAGE CHANNEL VELOCITIES



BOLSA BAY, CALIFORNIA

NENNC1
Location of links for displaying average channel velocities
under navigable entrance channel and non-navigable connector channel to Huntington Harbour conditions

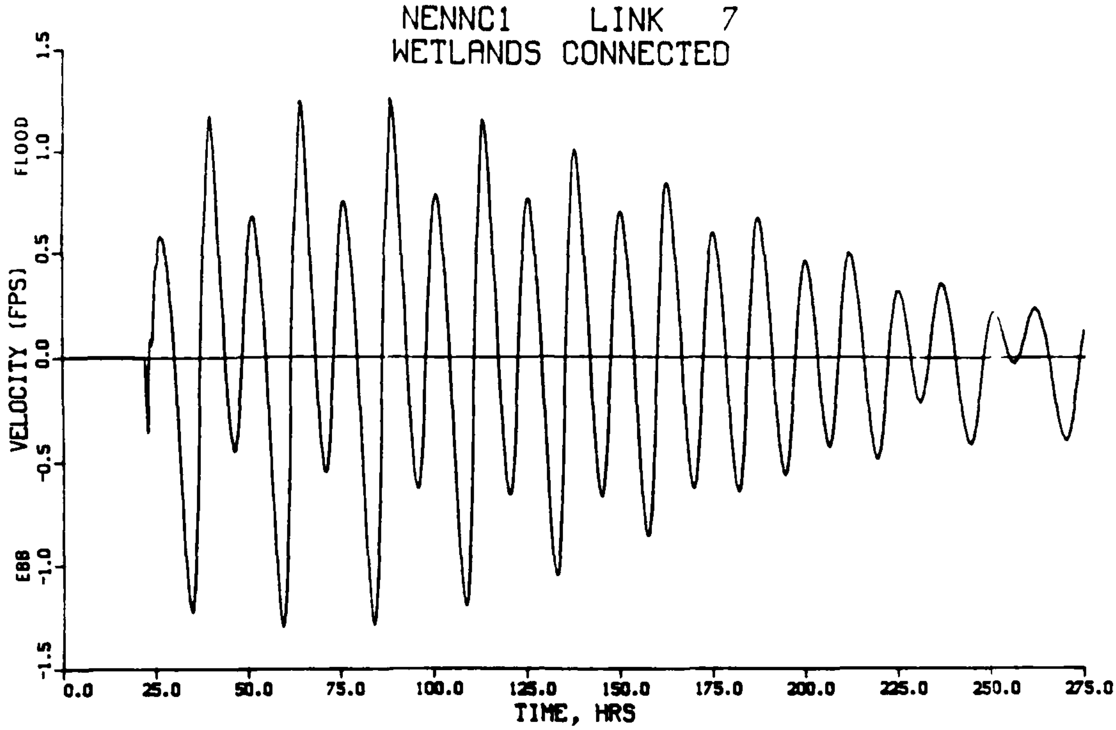


Figure F1. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

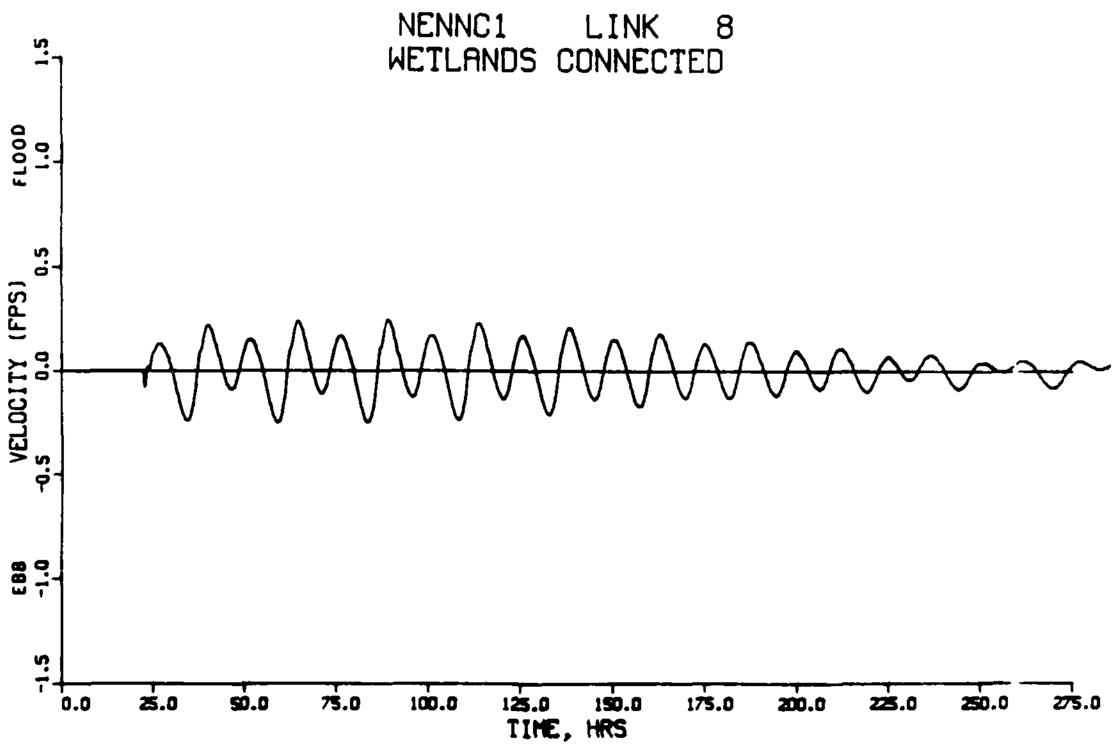


Figure F2. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

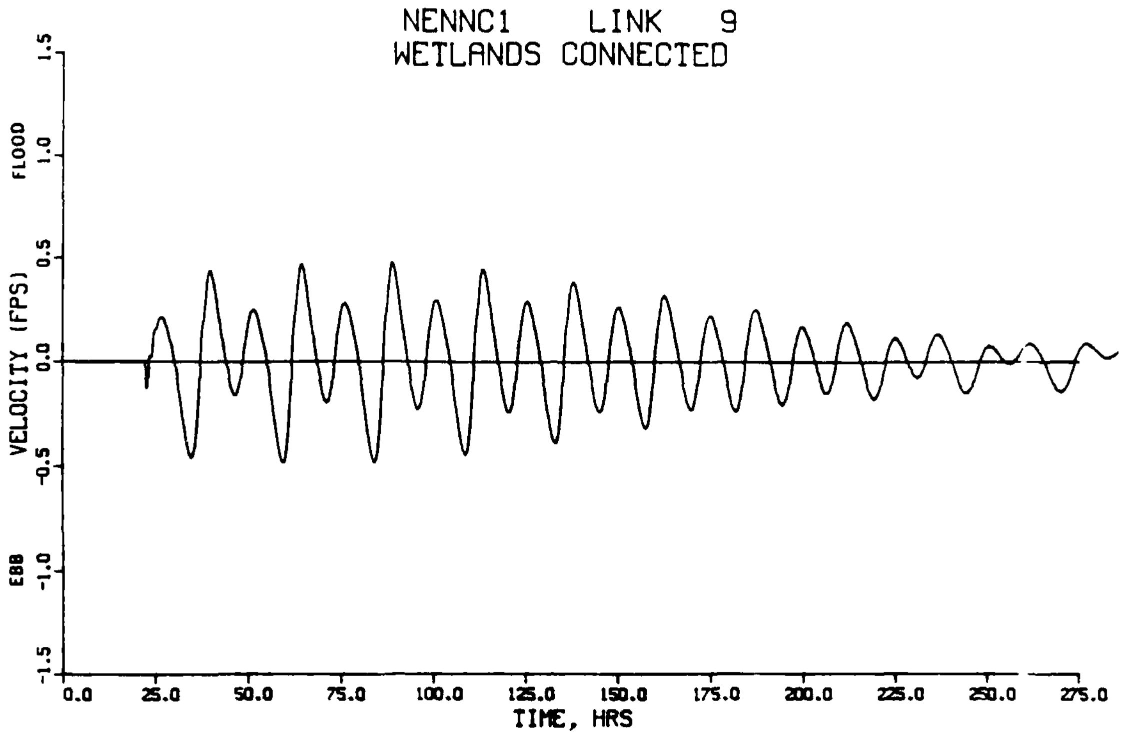


Figure F3. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

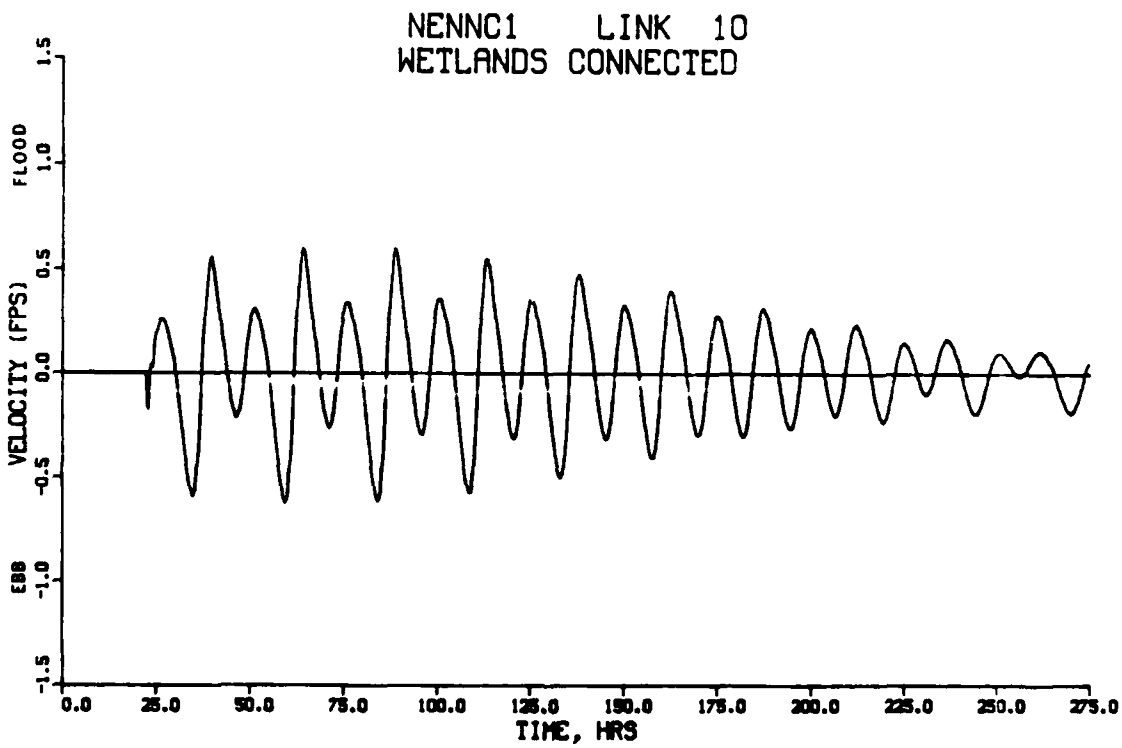


Figure F4. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

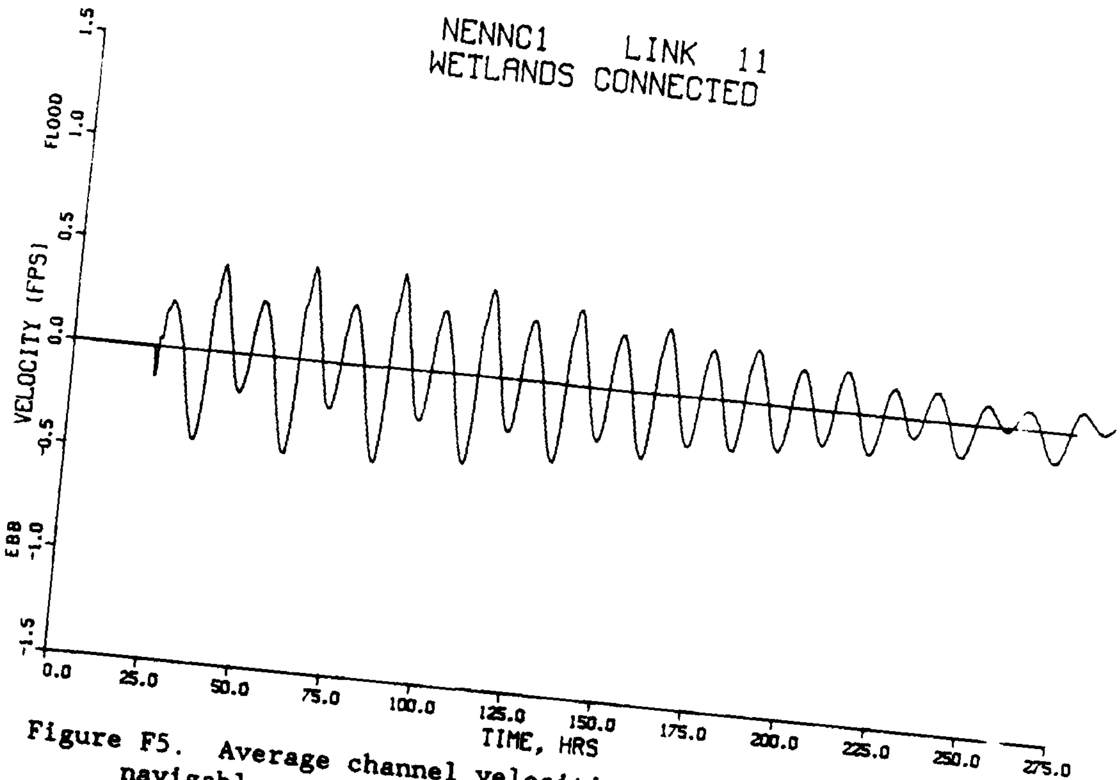


Figure F5. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

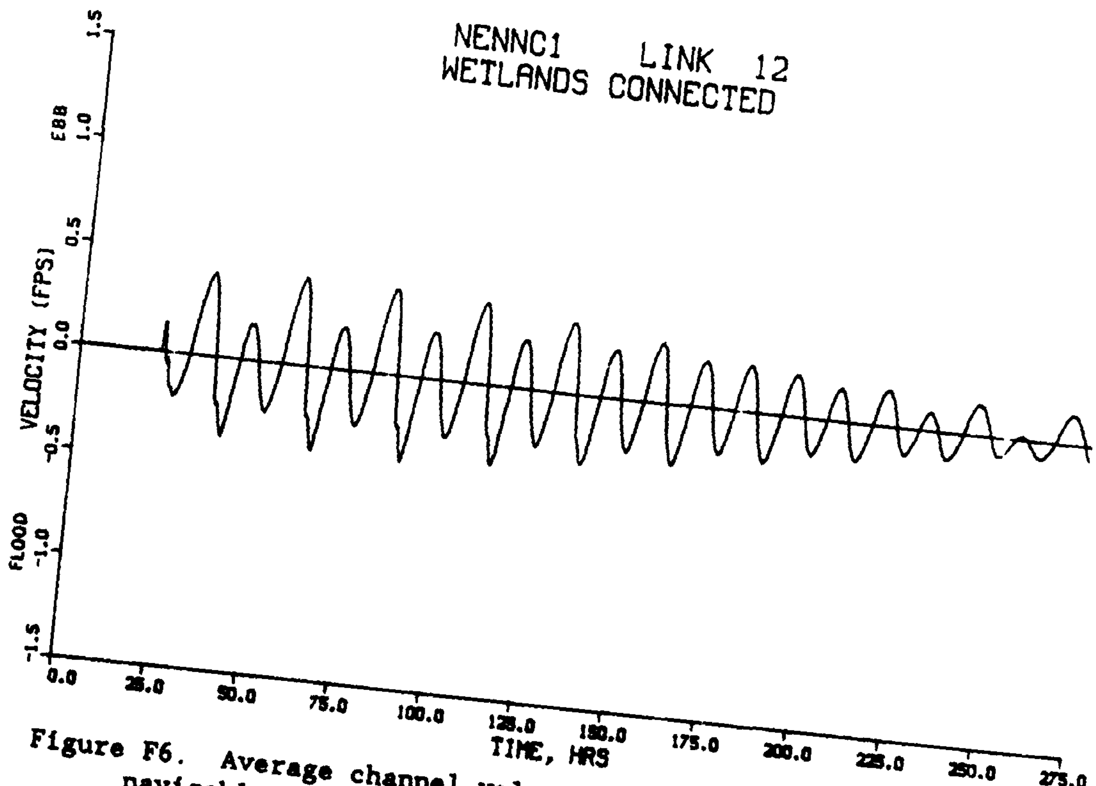


Figure F6. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

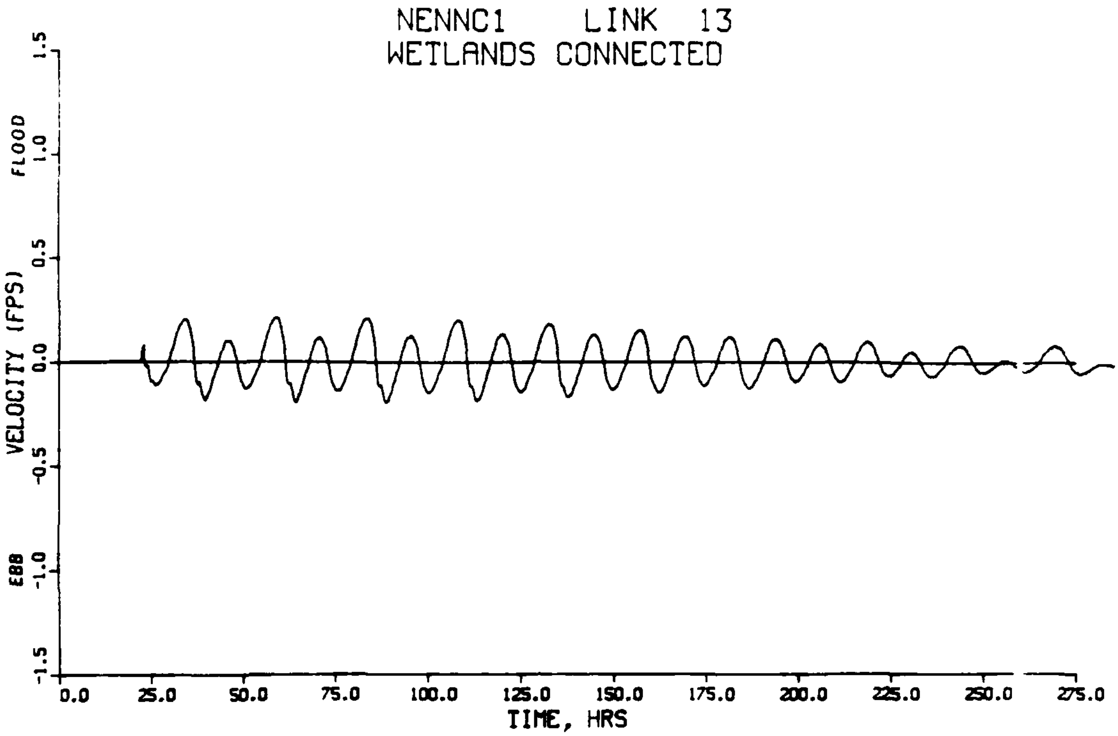


Figure F7. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

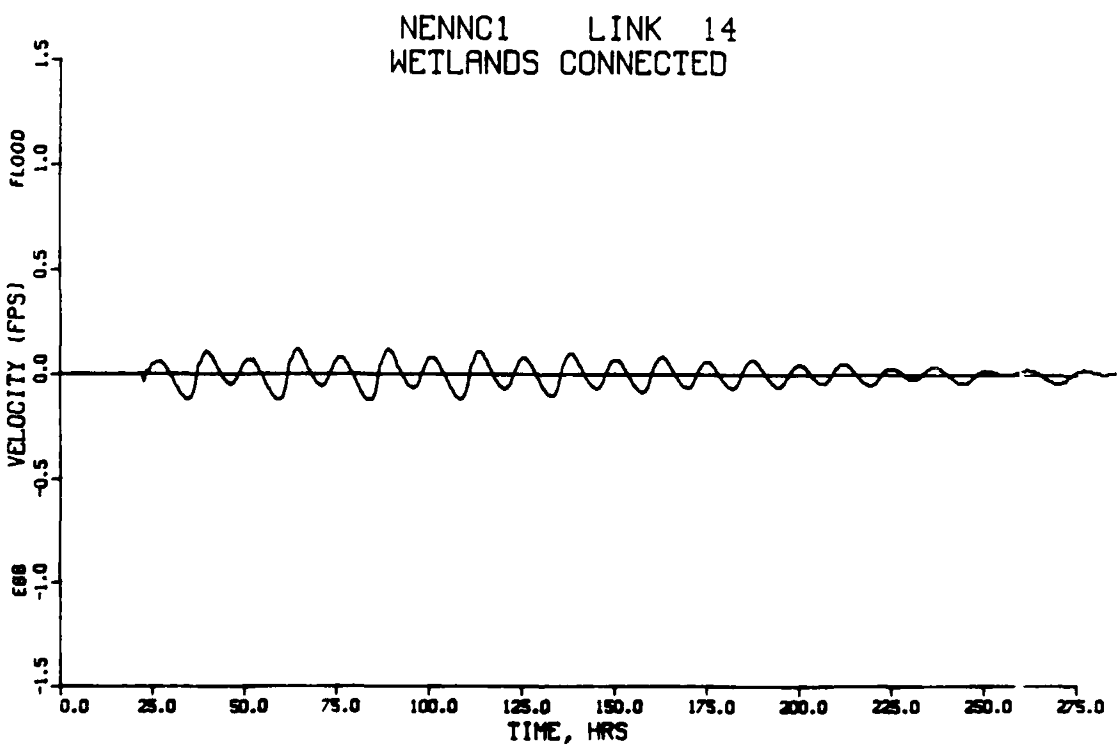


Figure F8. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

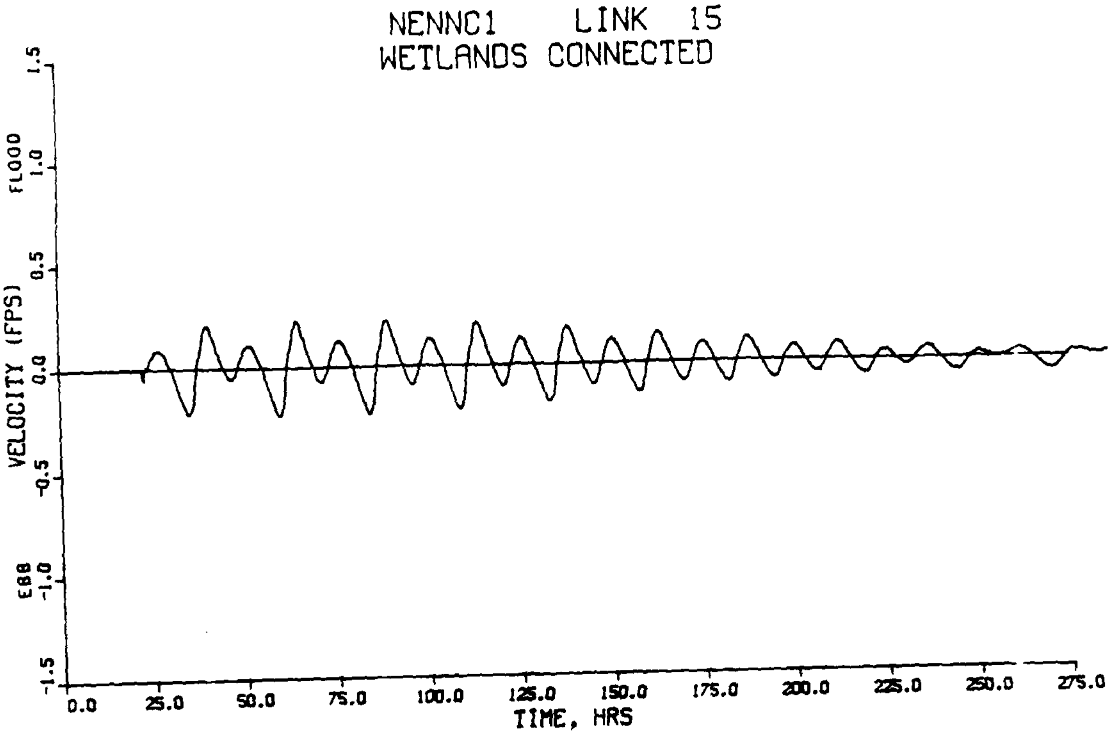


Figure F9. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

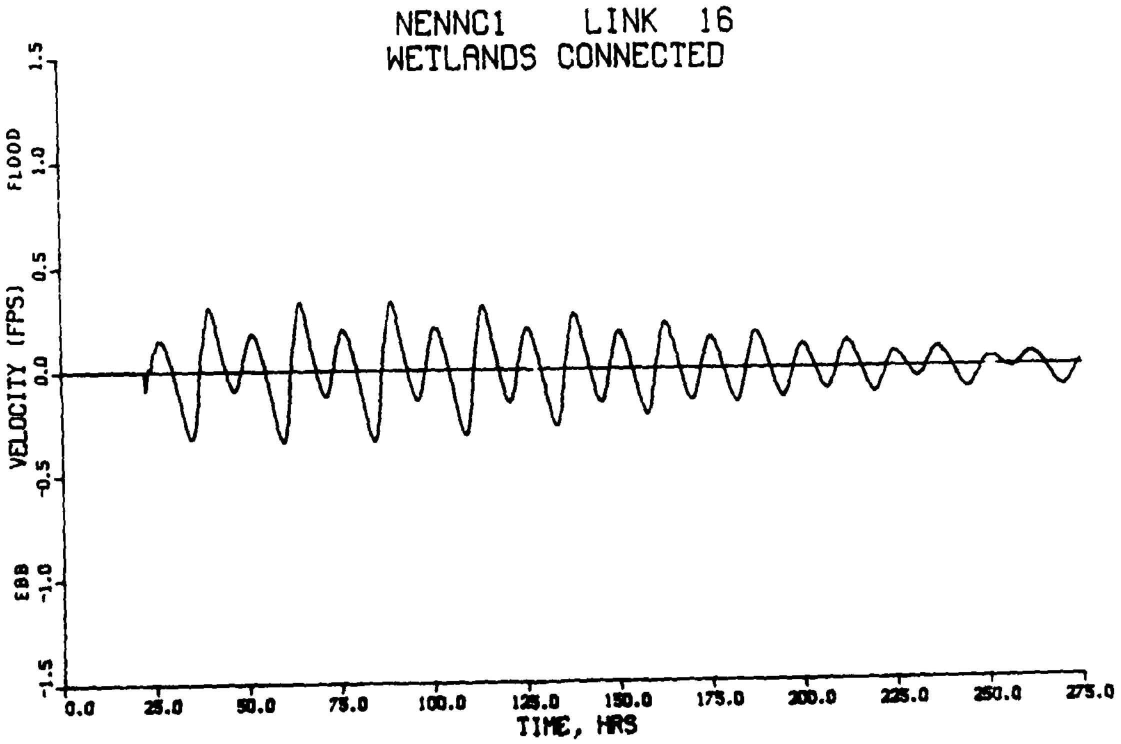


Figure F10. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

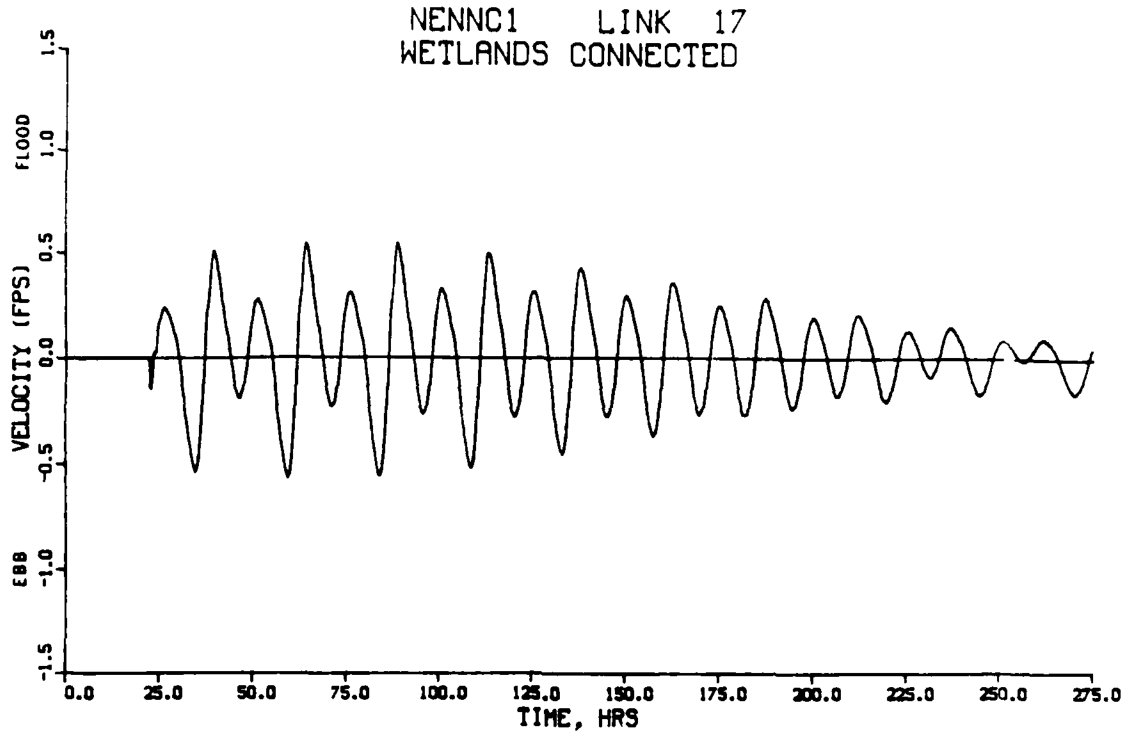


Figure F11. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

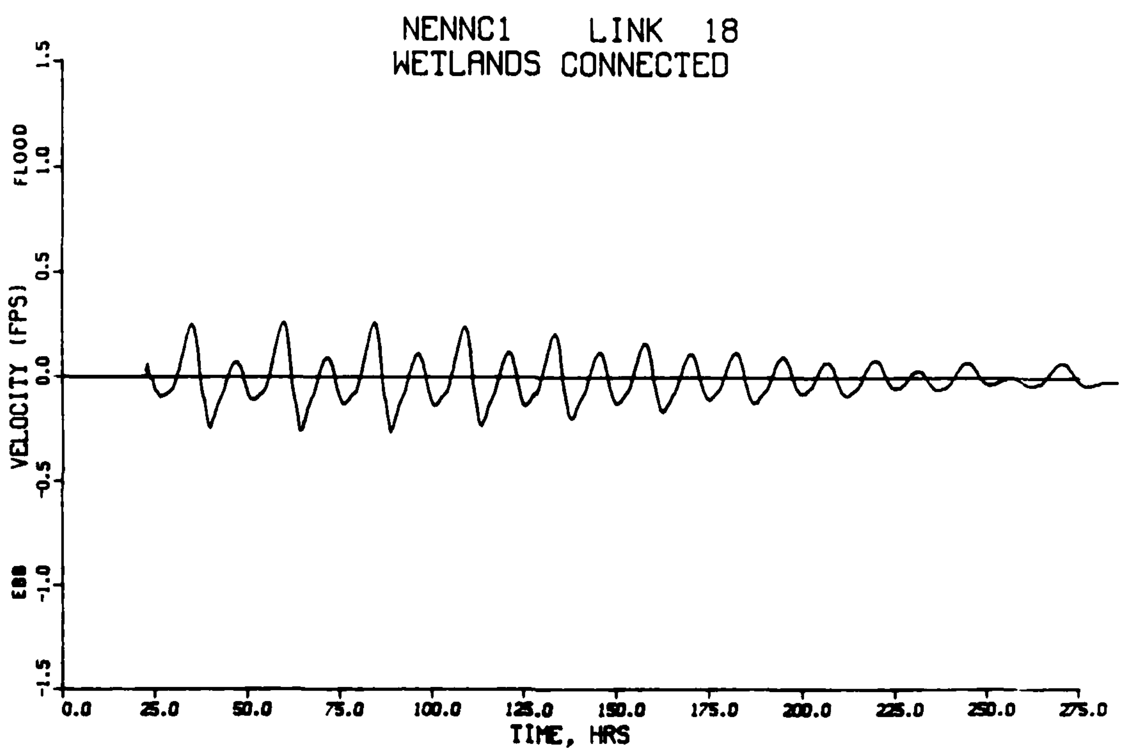


Figure F12. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

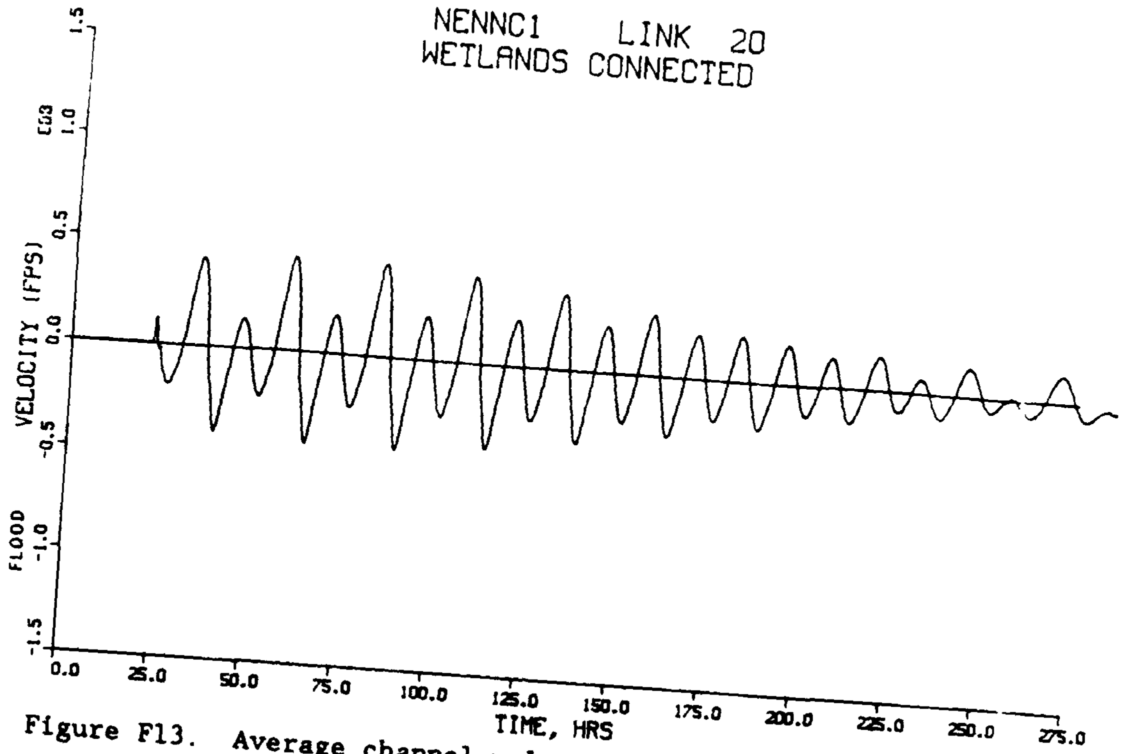


Figure F13. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

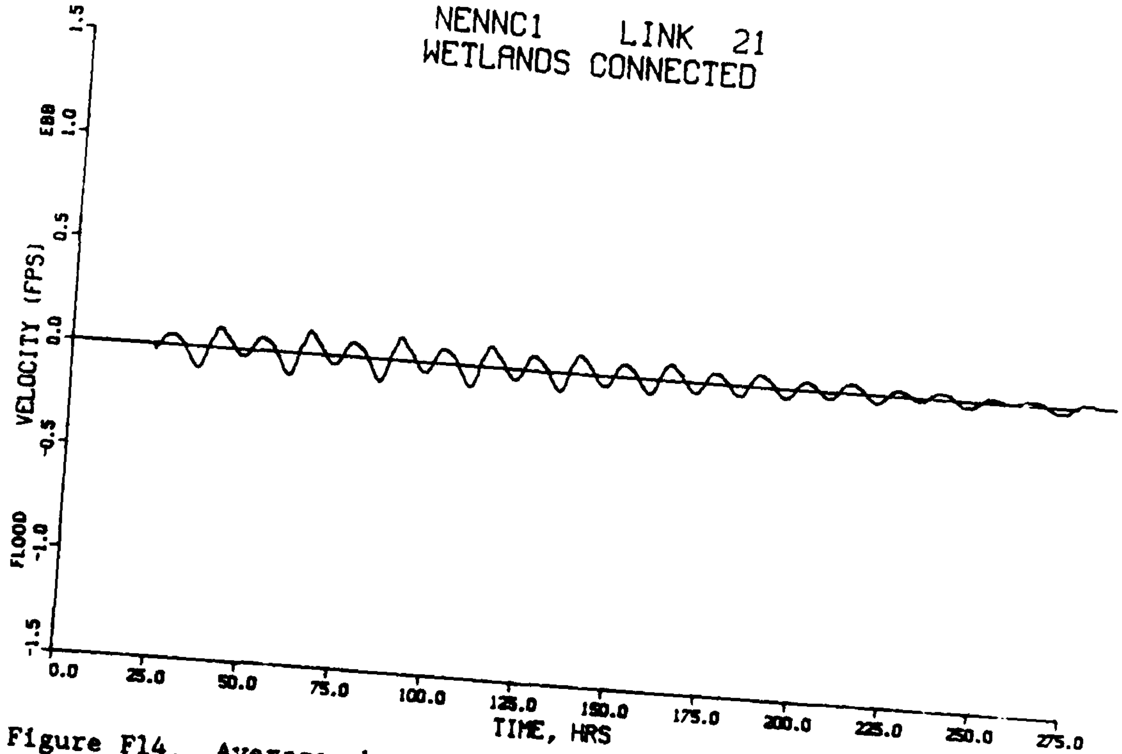


Figure F14. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

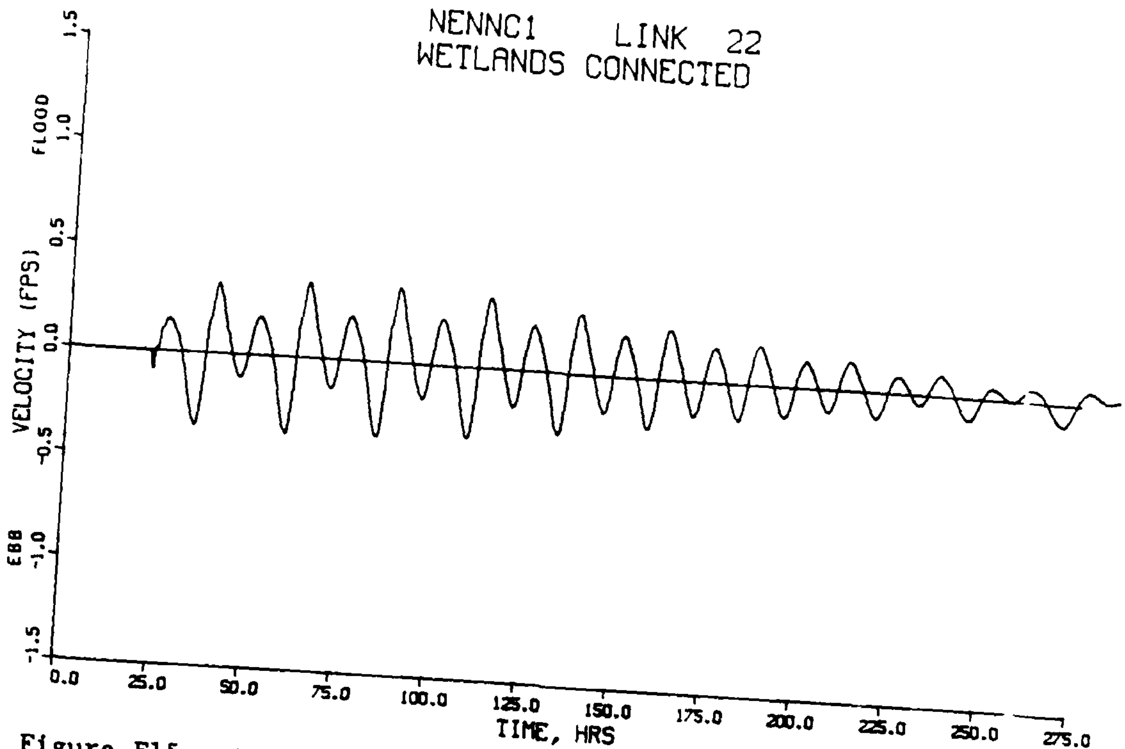


Figure F15. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

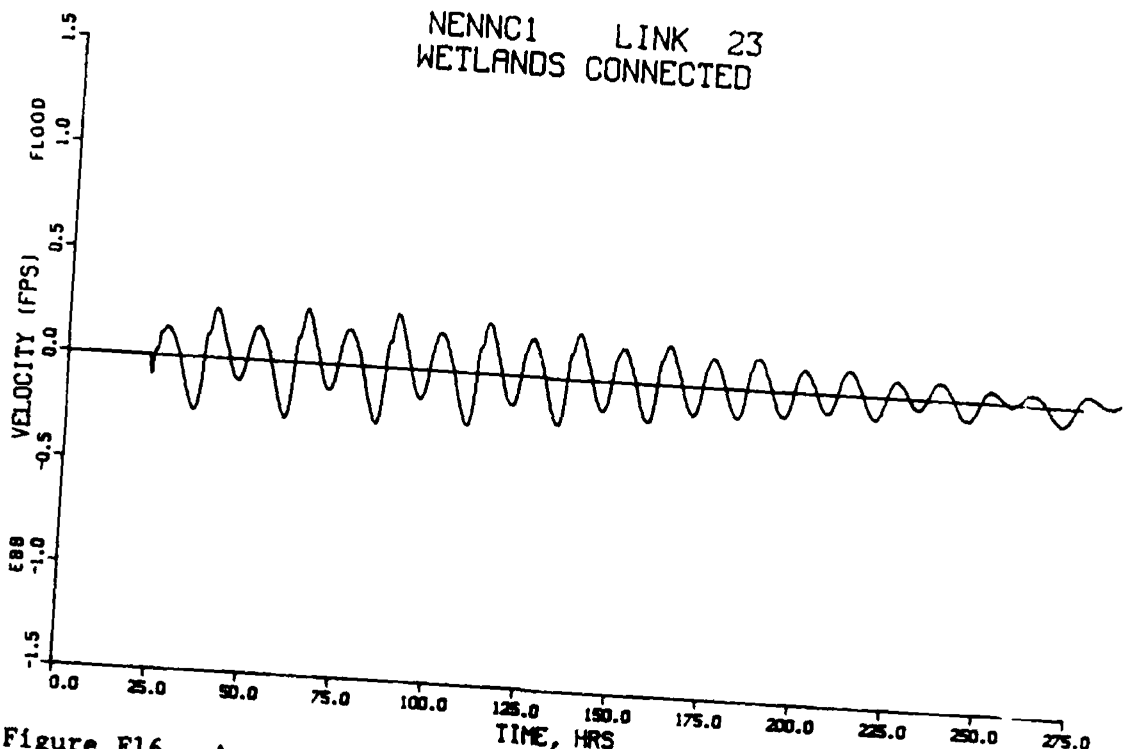


Figure F16. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

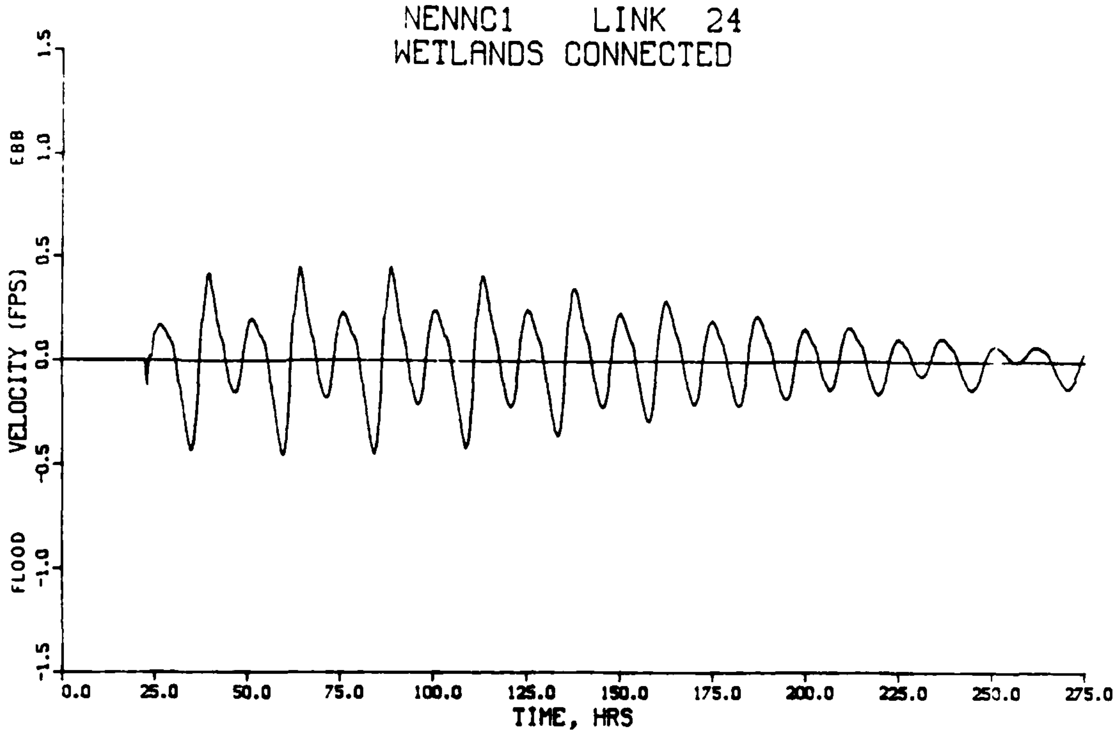


Figure F17. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

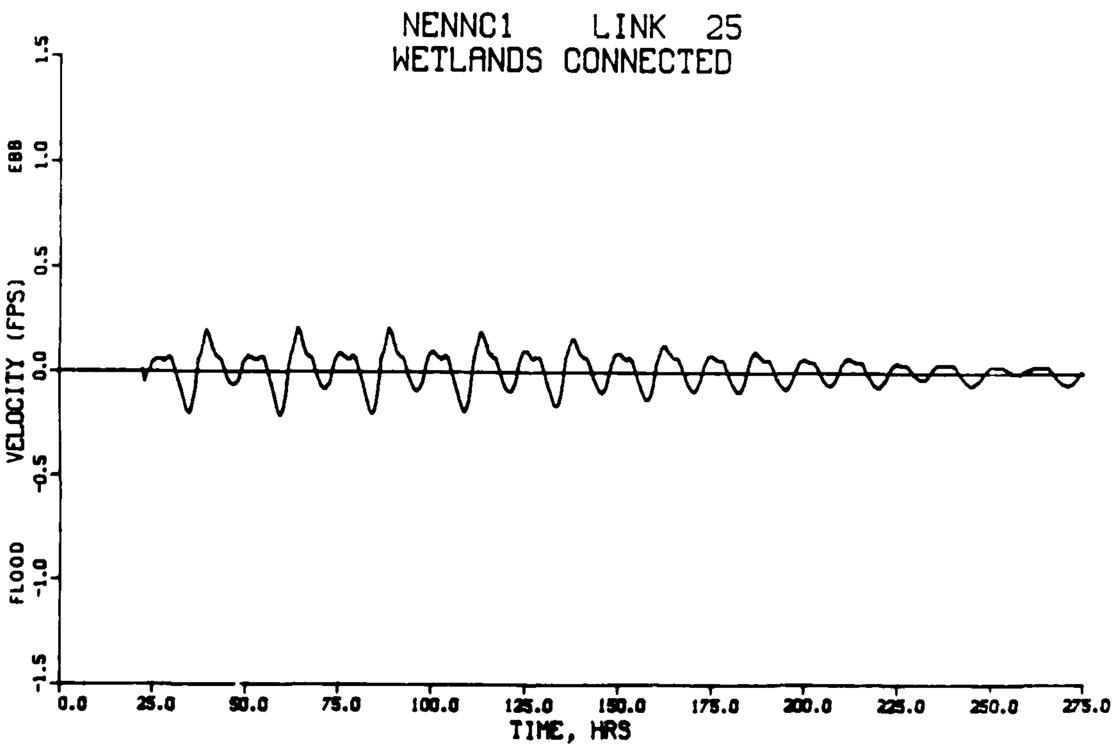


Figure F18. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

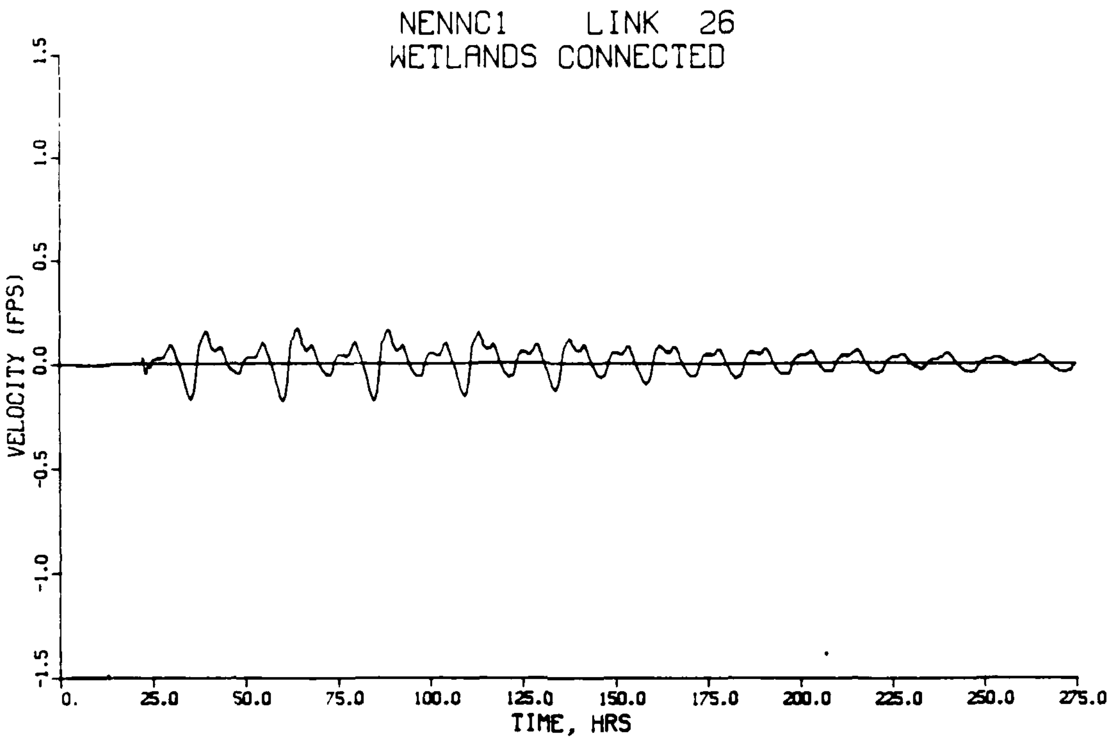


Figure F19. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

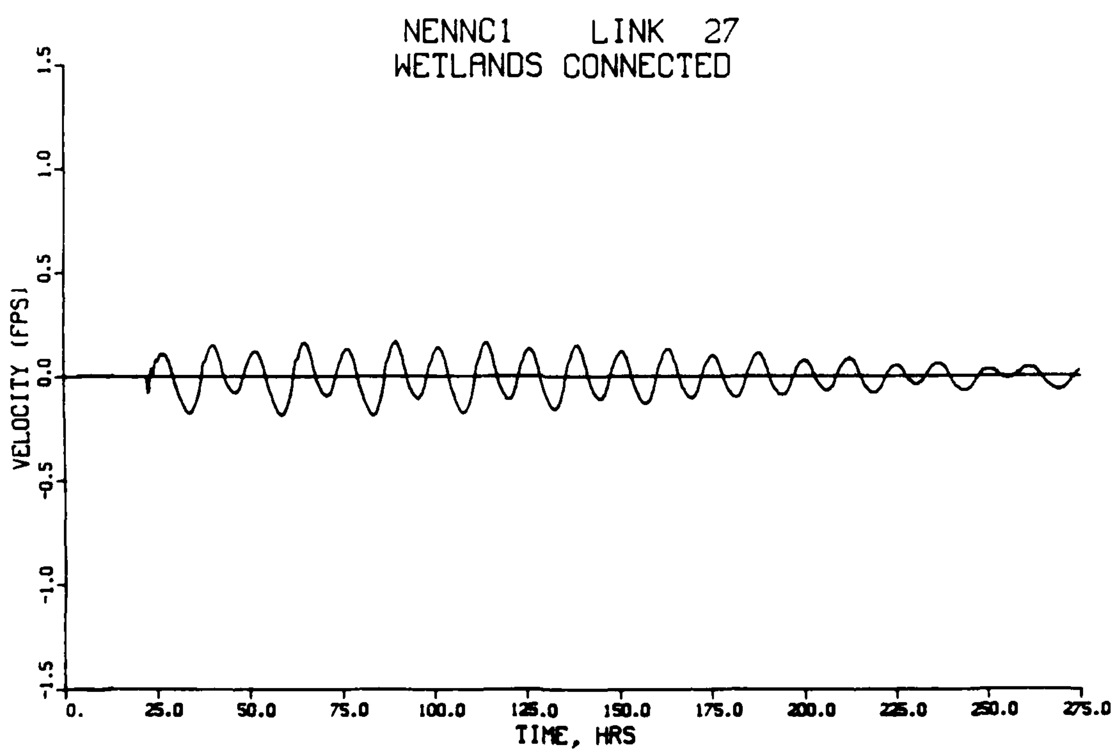


Figure F20. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

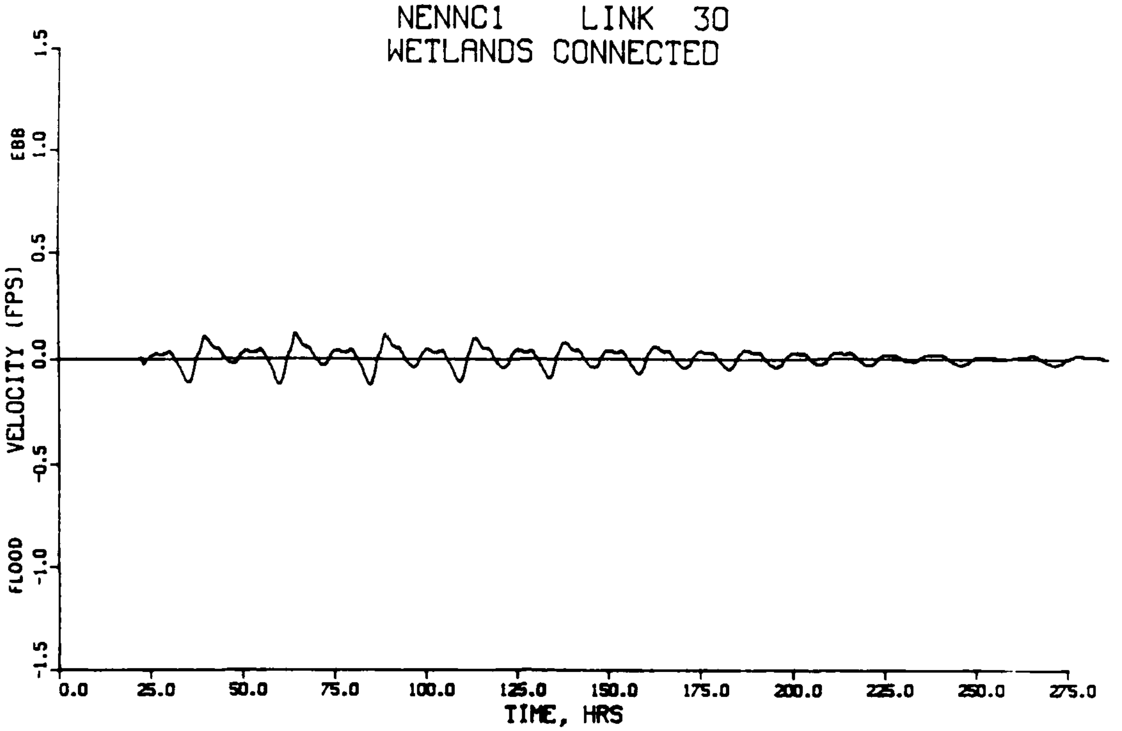


Figure F21. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

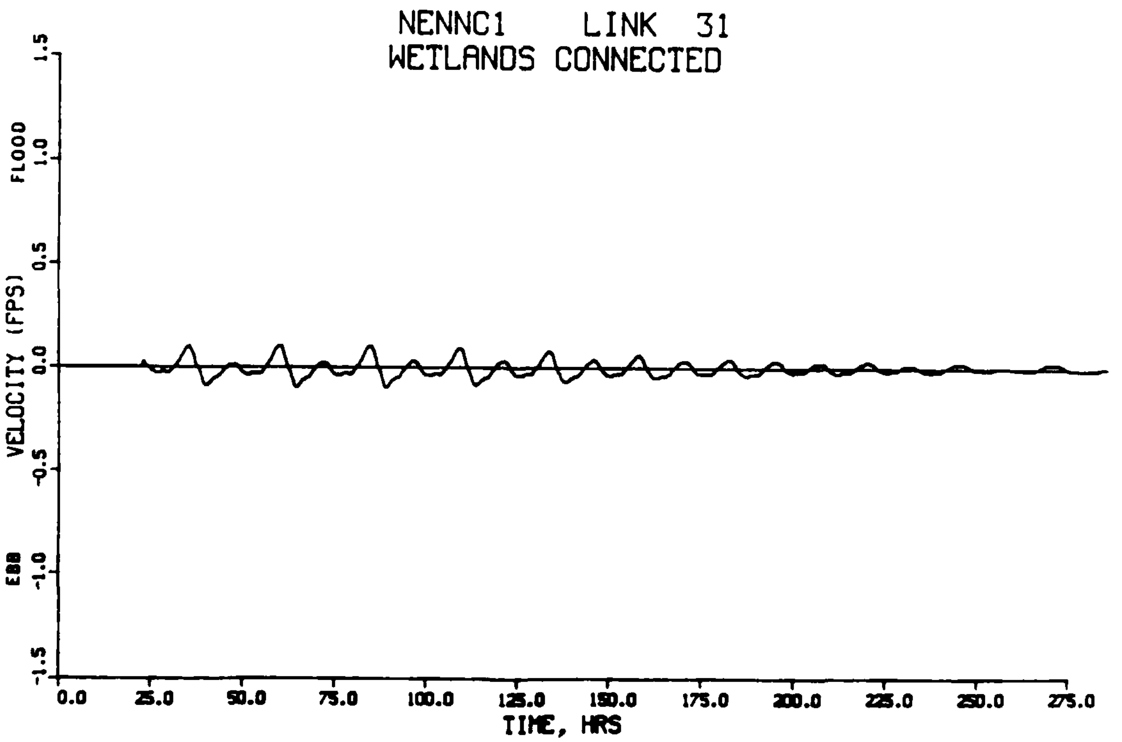


Figure F22. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

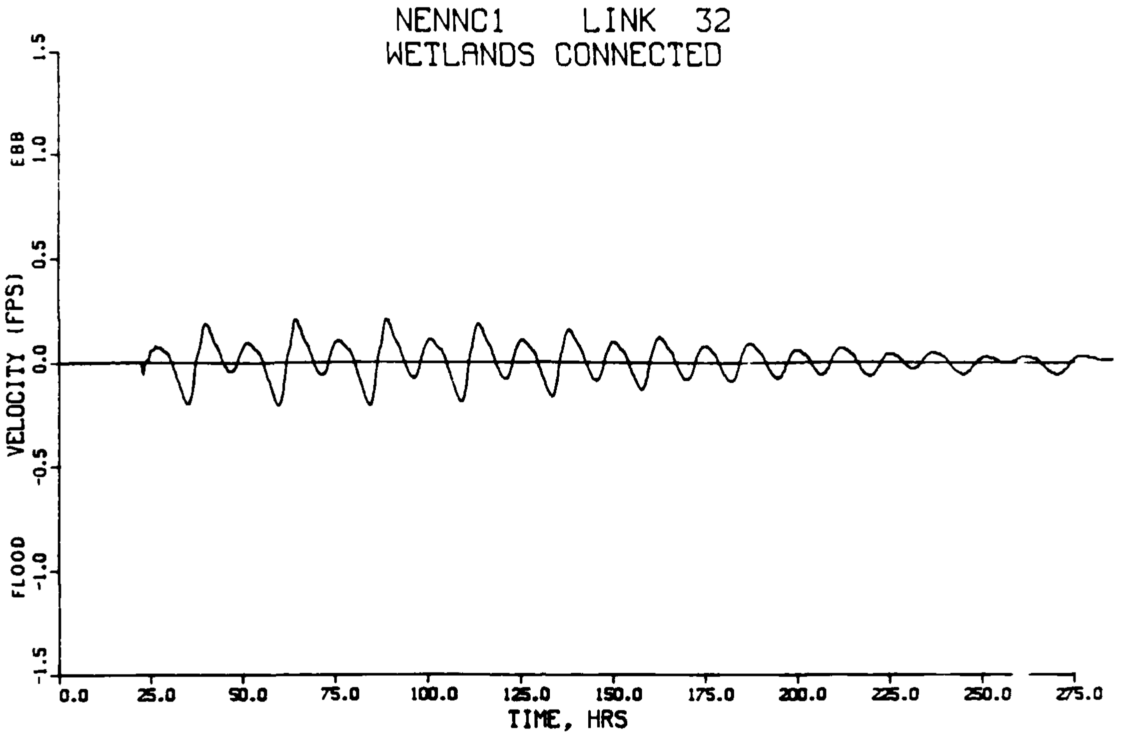


Figure F23. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

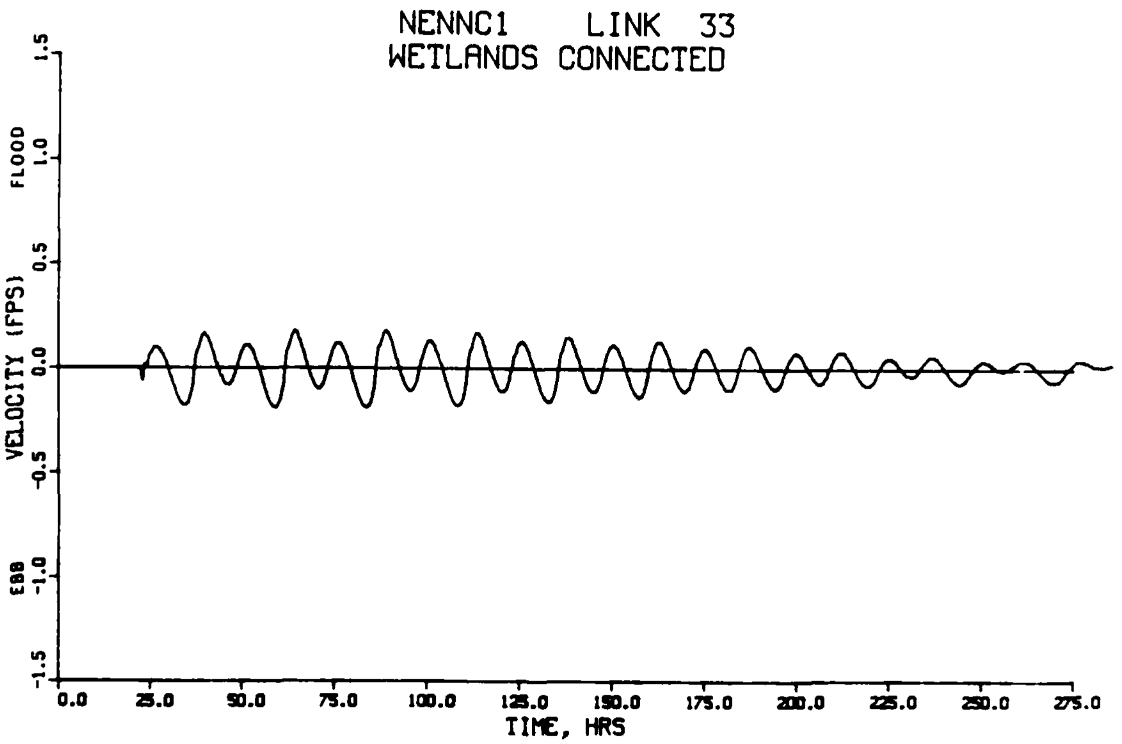


Figure F24. Average channel velocities in Huntington Harbour under navigable entrance, non-navigable connector conditions

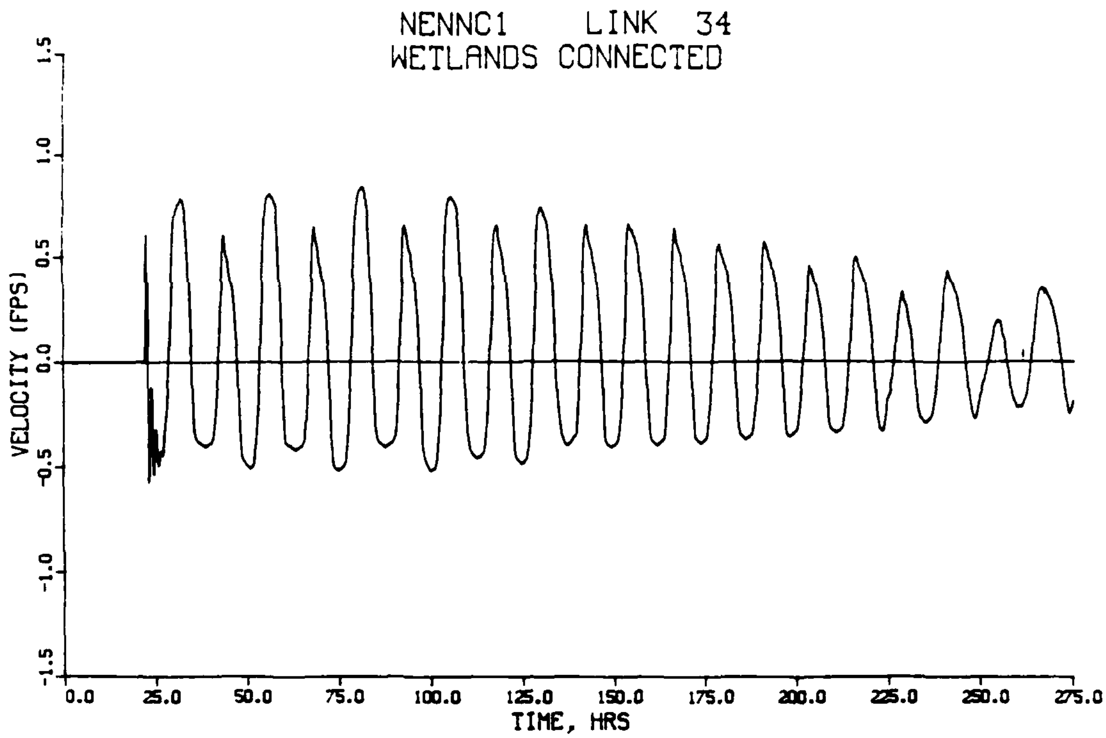


Figure F25. Average channel velocities at Warner Avenue under navigable entrance, non-navigable connector conditions

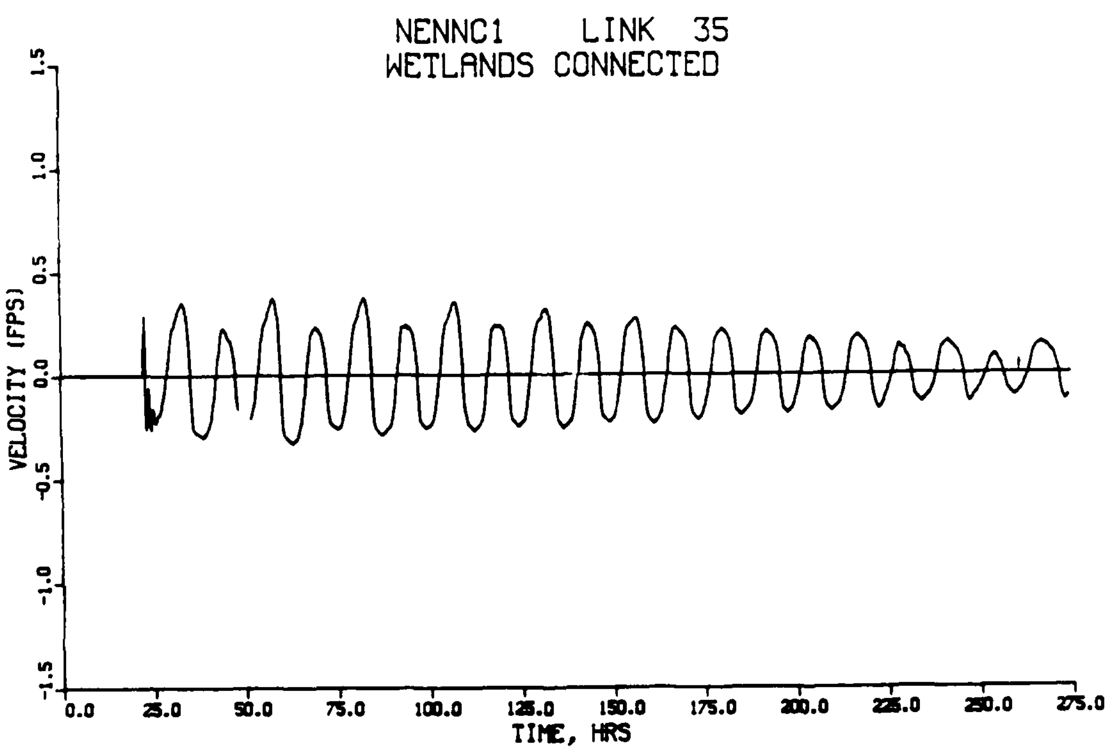


Figure F26. Average channel velocities in Outer Bolsa Bay under navigable entrance, non-navigable connector conditions

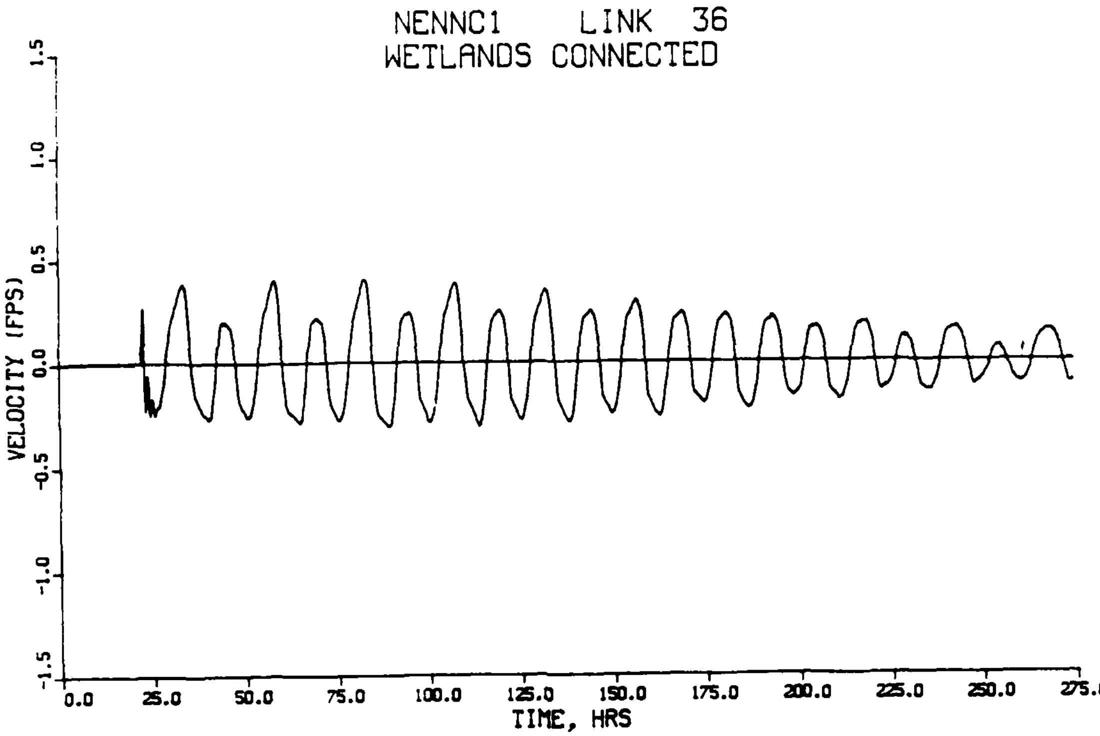


Figure F27. Average channel velocities in Outer Bolsa Bay under navigable entrance, non-navigable connector conditions

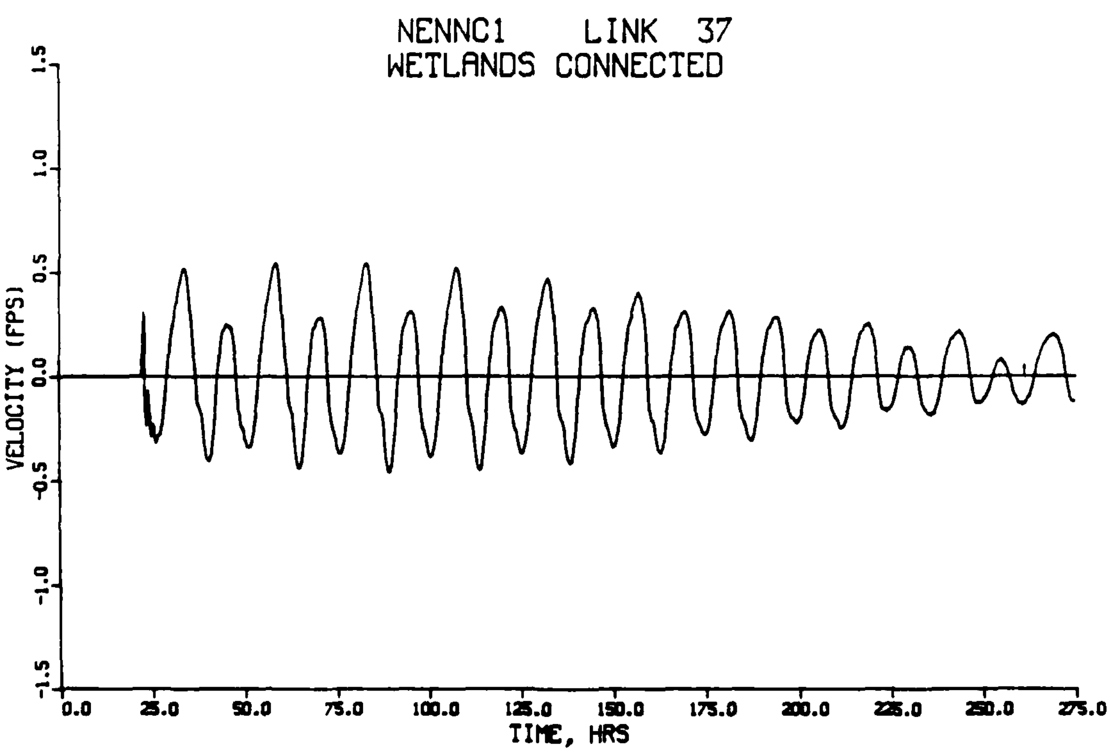


Figure F28. Average channel velocities in Outer Bolsa Bay under navigable entrance, non-navigable connector conditions

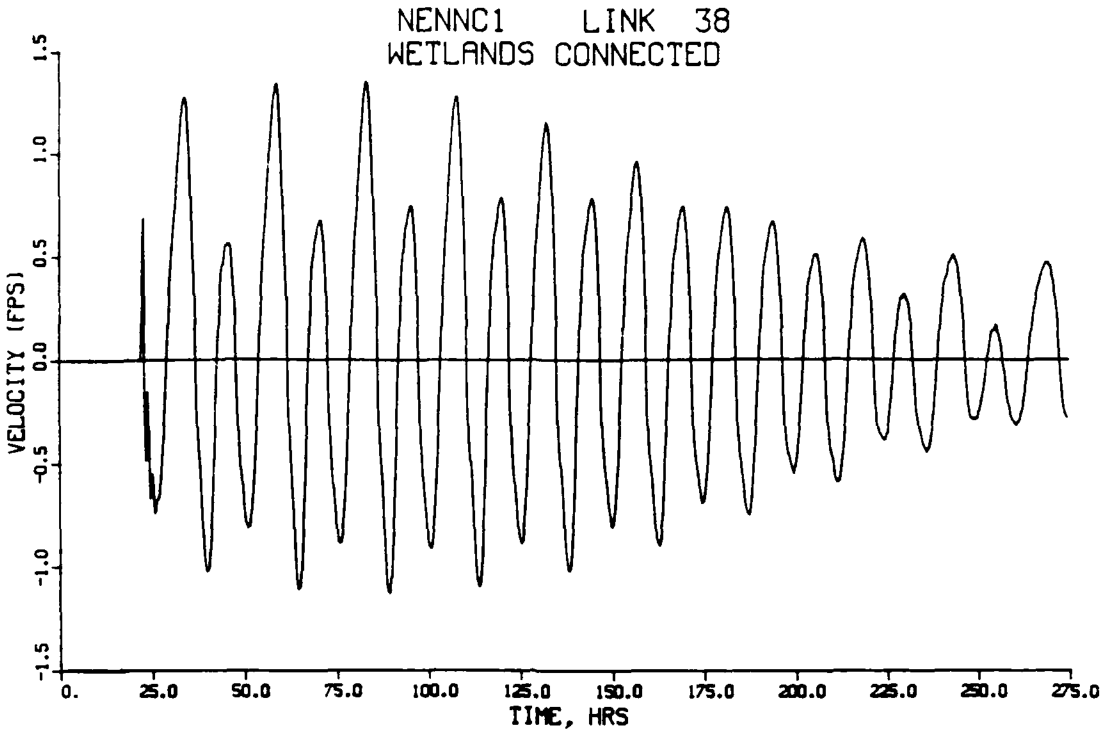


Figure F29. Average channel velocities in Outer Bolsa Bay under navigable entrance, non-navigable connector conditions

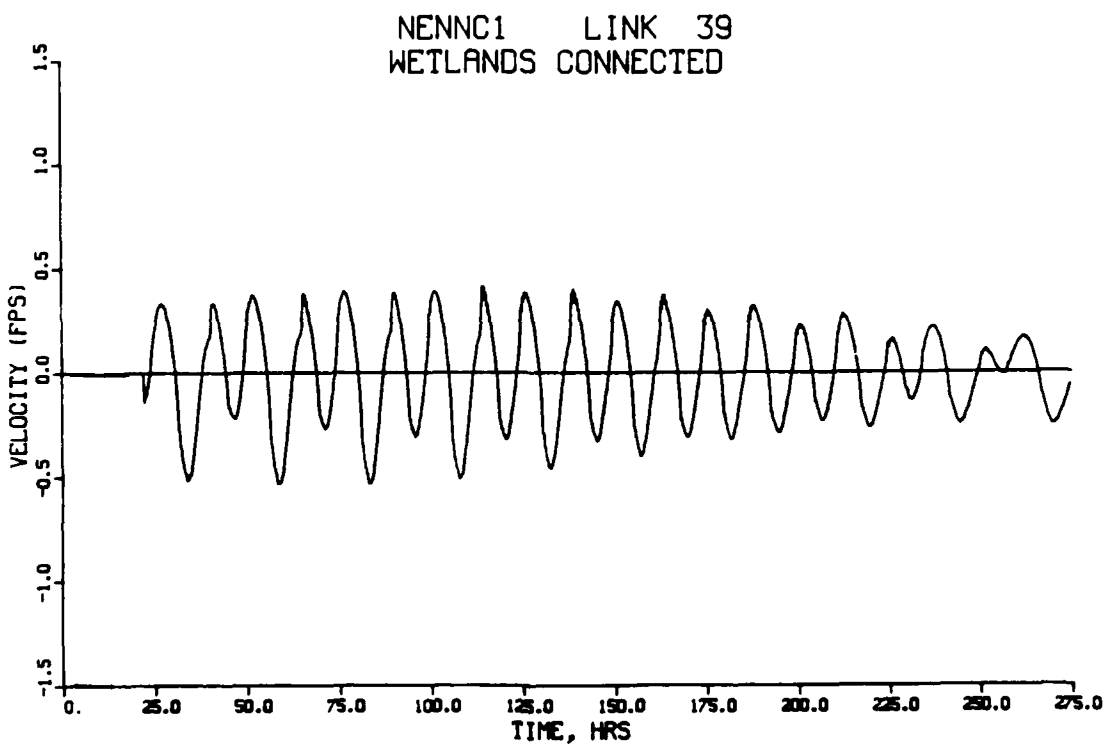


Figure F30. Average channel velocities in proposed marina under navigable entrance, non-navigable connector conditions

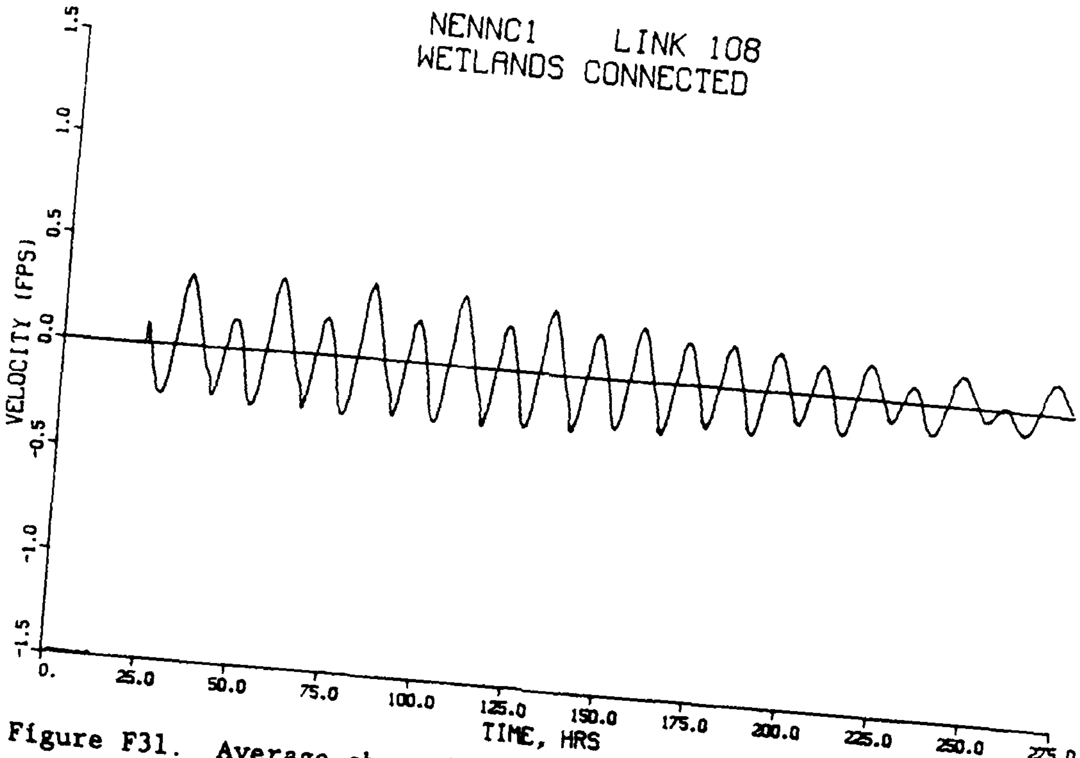


Figure F31. Average channel velocities in entrance channel under navigable entrance, non-navigable connector conditions

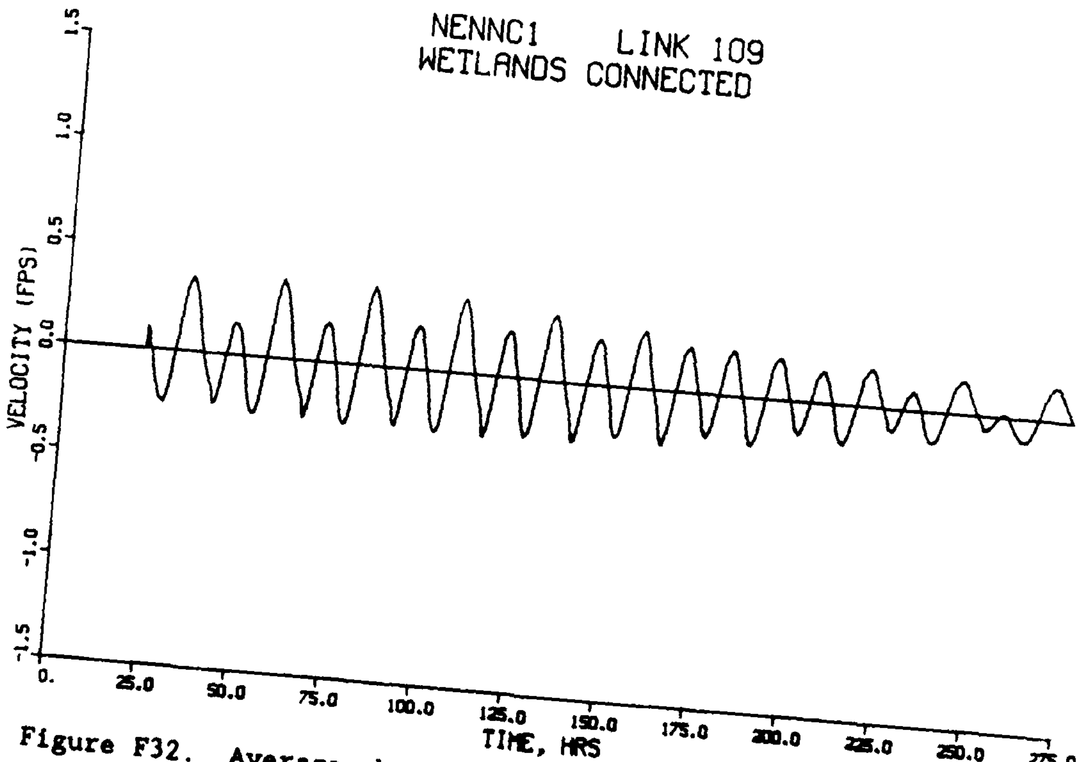


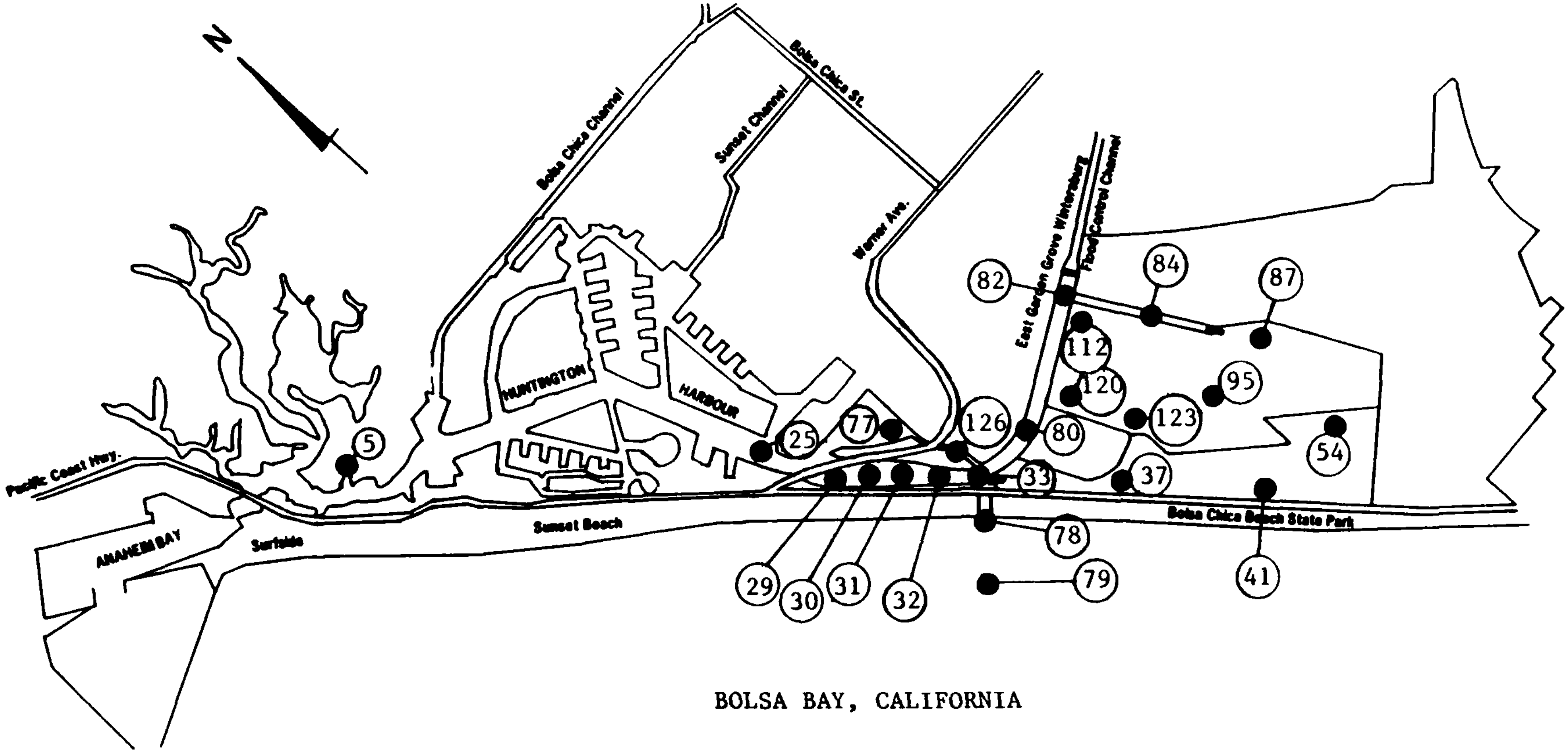
Figure F32. Average channel velocities in entrance channel under navigable entrance, non-navigable connector conditions

APPENDIX G:

NNECC3

NON-NAVIGABLE ENTRANCE CHANNEL
AND
BY-PASS CONNECTOR CHANNEL TO MARINA

WATER SURFACE ELEVATIONS



BOLSA BAY, CALIFORNIA

NNECC3
Location of nodes for displaying water surface elevations
under non-navigable entrance channel and by-pass connector channel to marina conditions

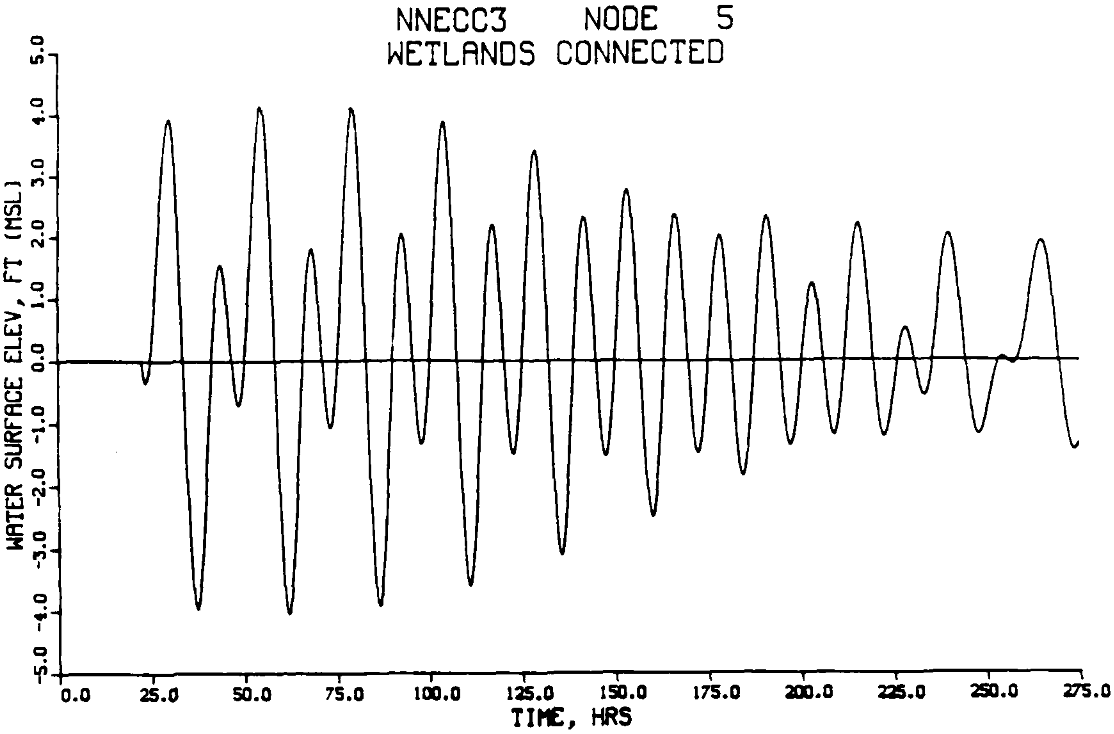


Figure G1. Tidal elevations in Huntington Harbour under non-navigable entrance, by-pass connector channel to marina conditions

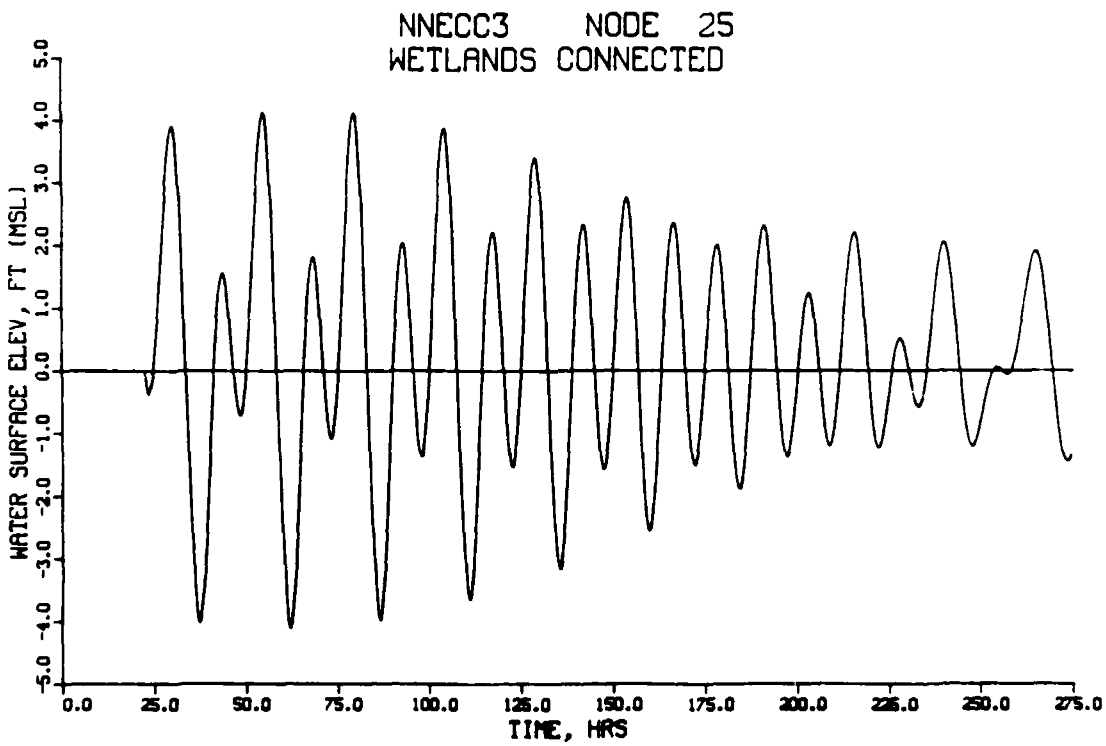


Figure G2. Tidal elevations in Huntington Harbour under non-navigable entrance, by-pass connector channel to marina conditions

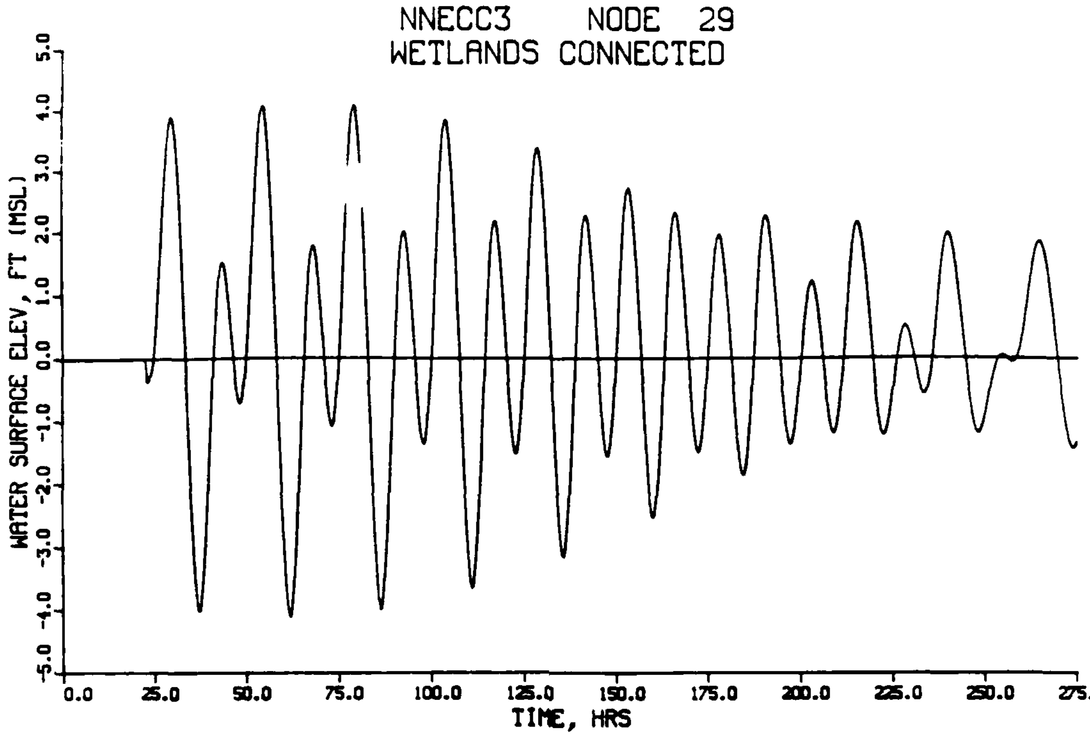


Figure G3. Tidal elevations in Outer Bolsa Bay under non-navigable entrance, by-pass connector channel to marina conditions

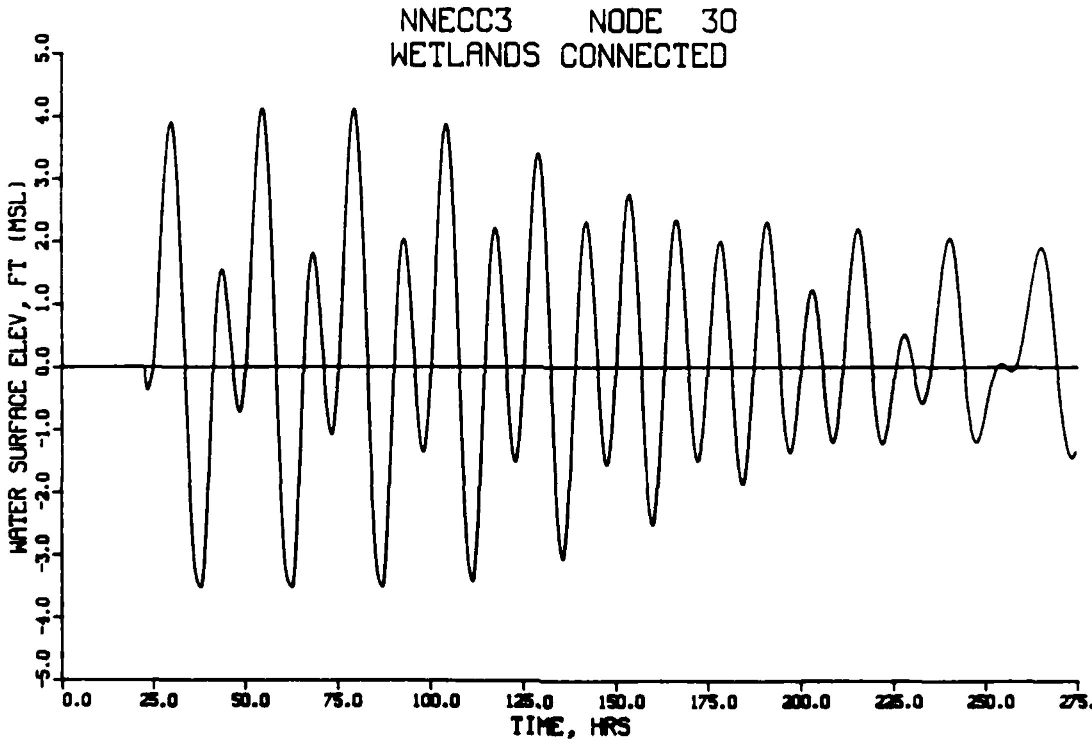


Figure G4. Tidal elevations in Outer Bolsa Bay under non-navigable entrance, by-pass connector channel to marina conditions

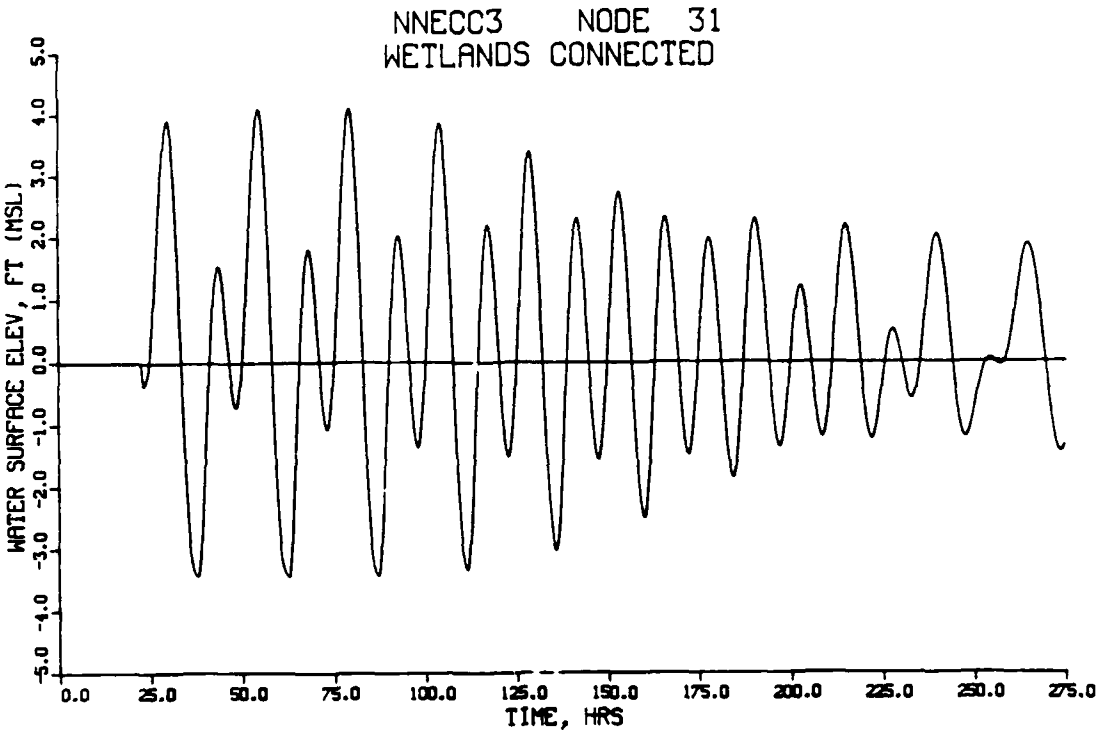


Figure G5. Tidal elevations in Outer Bolsa Bay under non-navigable entrance, by-pass connector channel to marina conditions

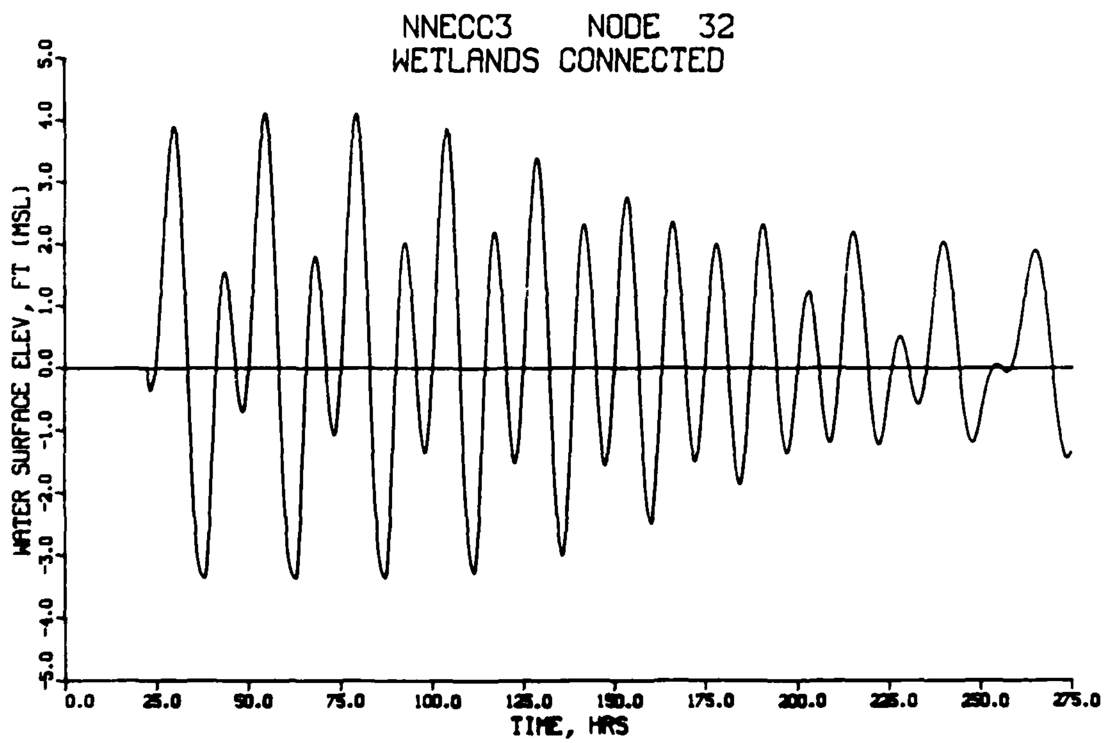


Figure G6. Tidal elevations in Outer Bolsa Bay under non-navigable entrance, by-pass connector channel to marina conditions

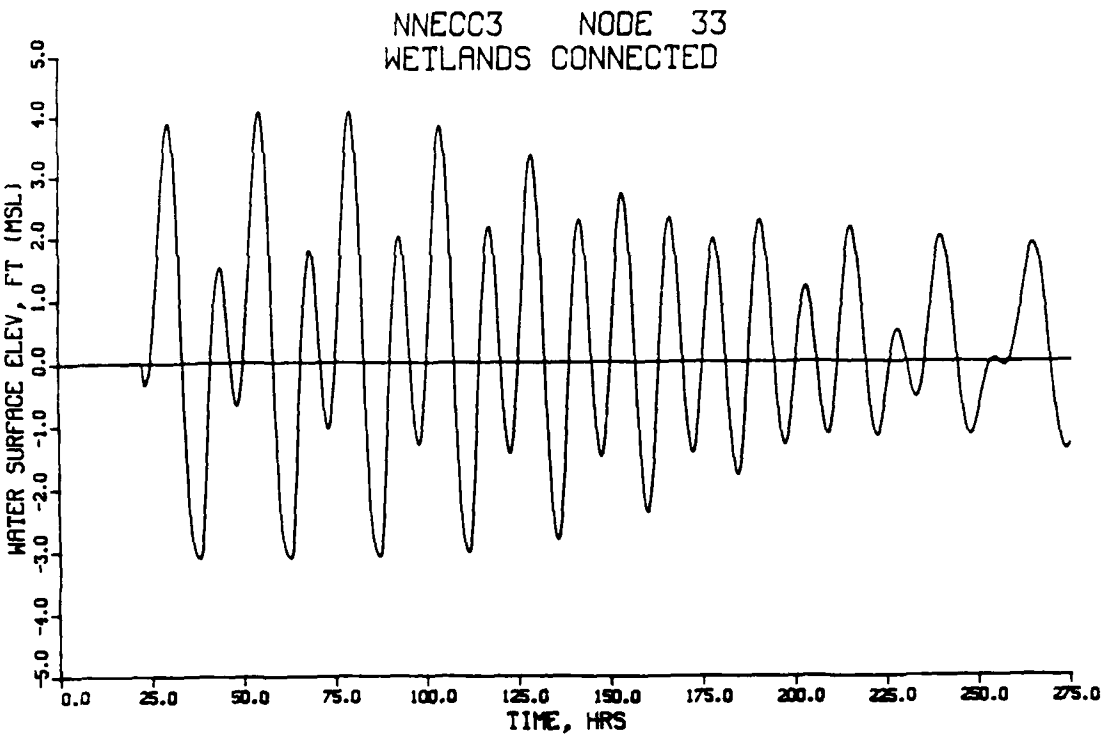


Figure G7. Tidal elevations in entrance channel under non-navigable entrance, by-pass connector channel to marina conditions

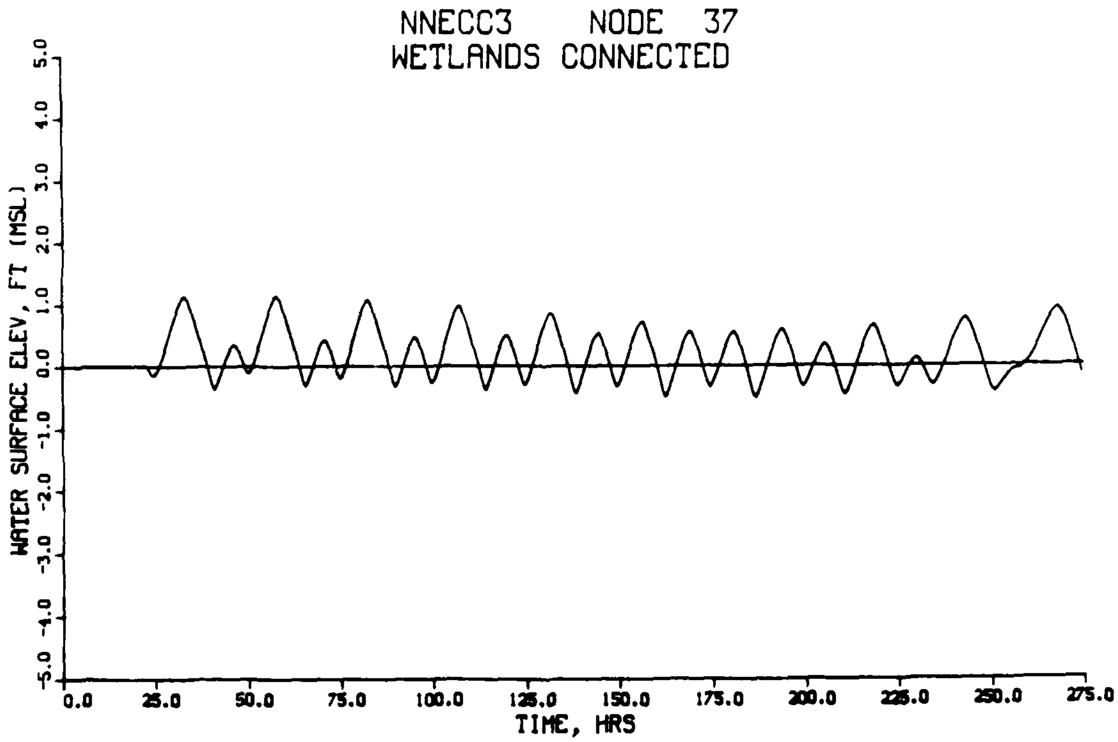


Figure G8. Tidal elevations in Inner Bolsa Bay under non-navigable entrance, by-pass connector channel to marina conditions

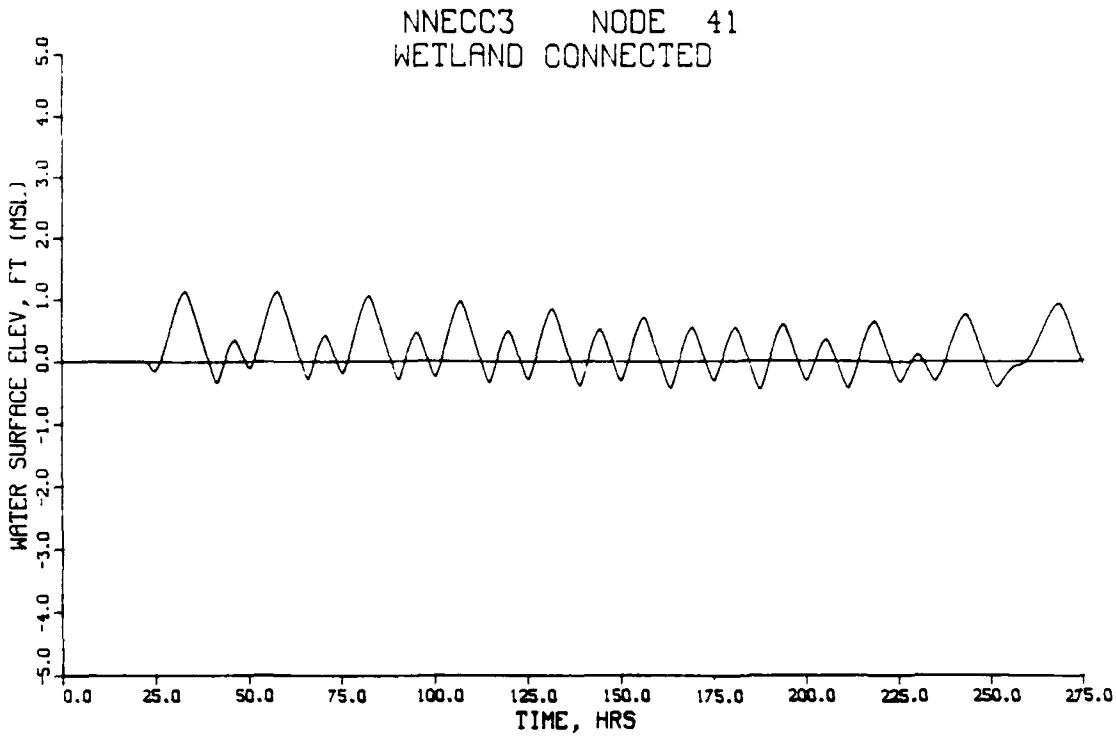


Figure G9. Tidal elevations in Inner Bolsa Bay under non-navigable entrance, by-pass connector channel to marina conditions

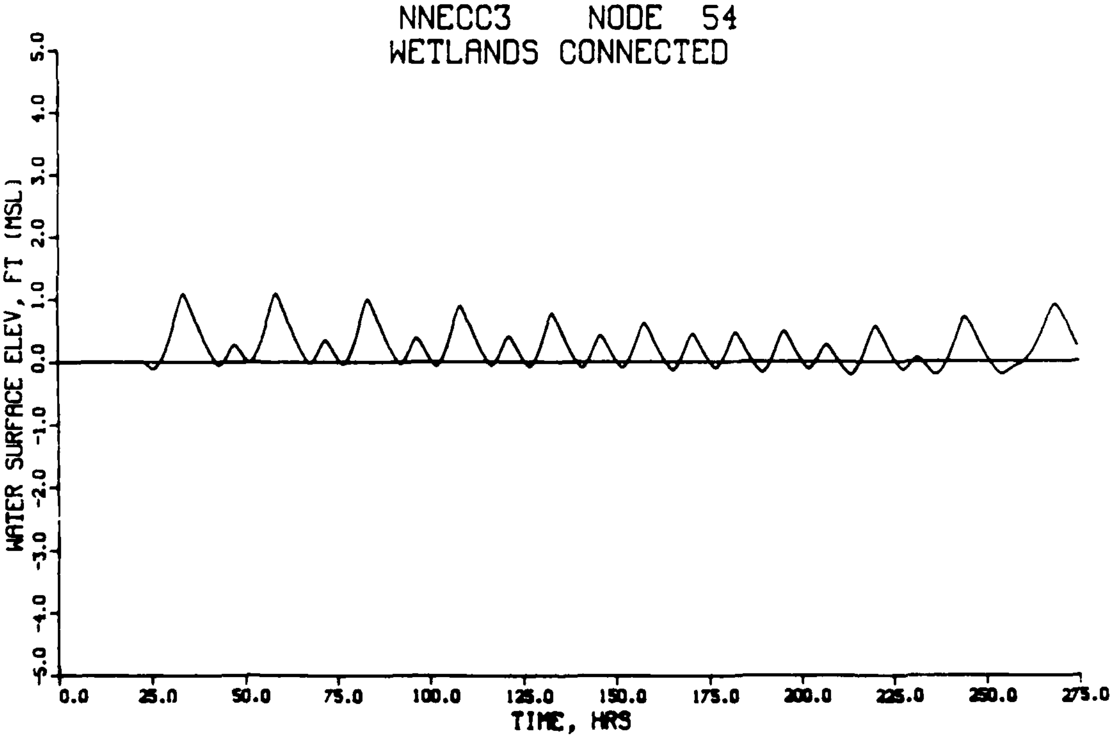


Figure G10. Tidal elevations in DFG muted tidal cell under non-navigable entrance, by-pass connector channel to marina conditions

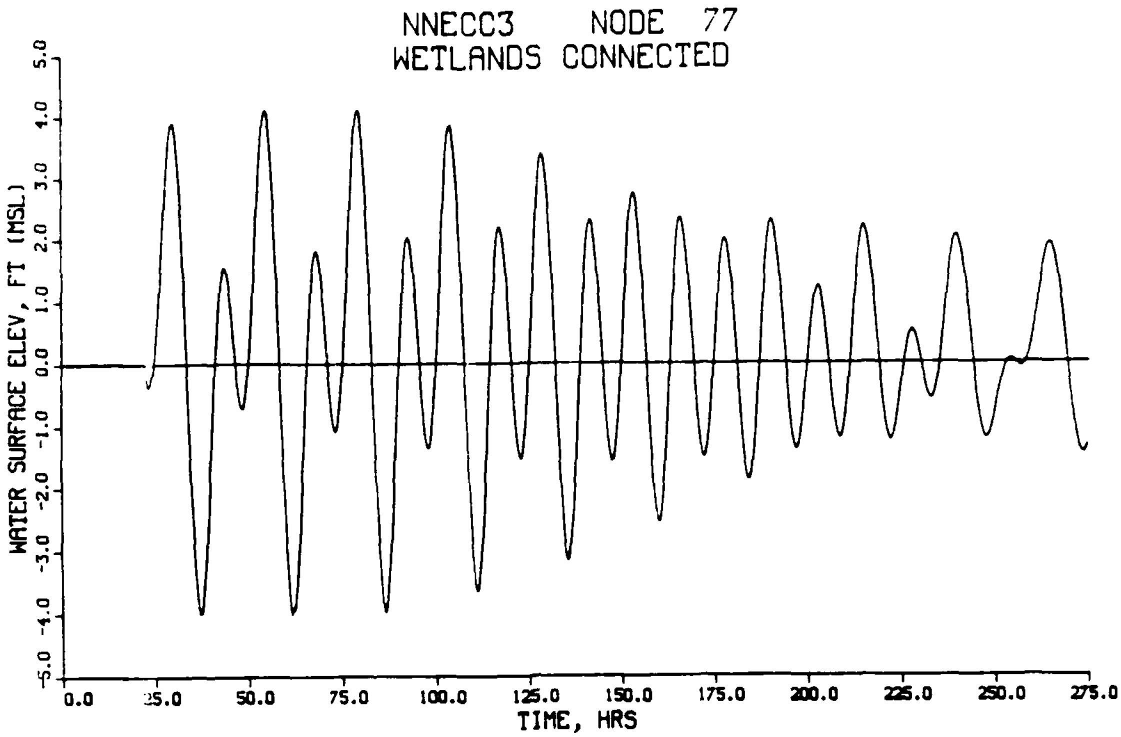


Figure G11. Tidal elevations in proposed marina under non-navigable entrance, by-pass connector channel to marina conditions

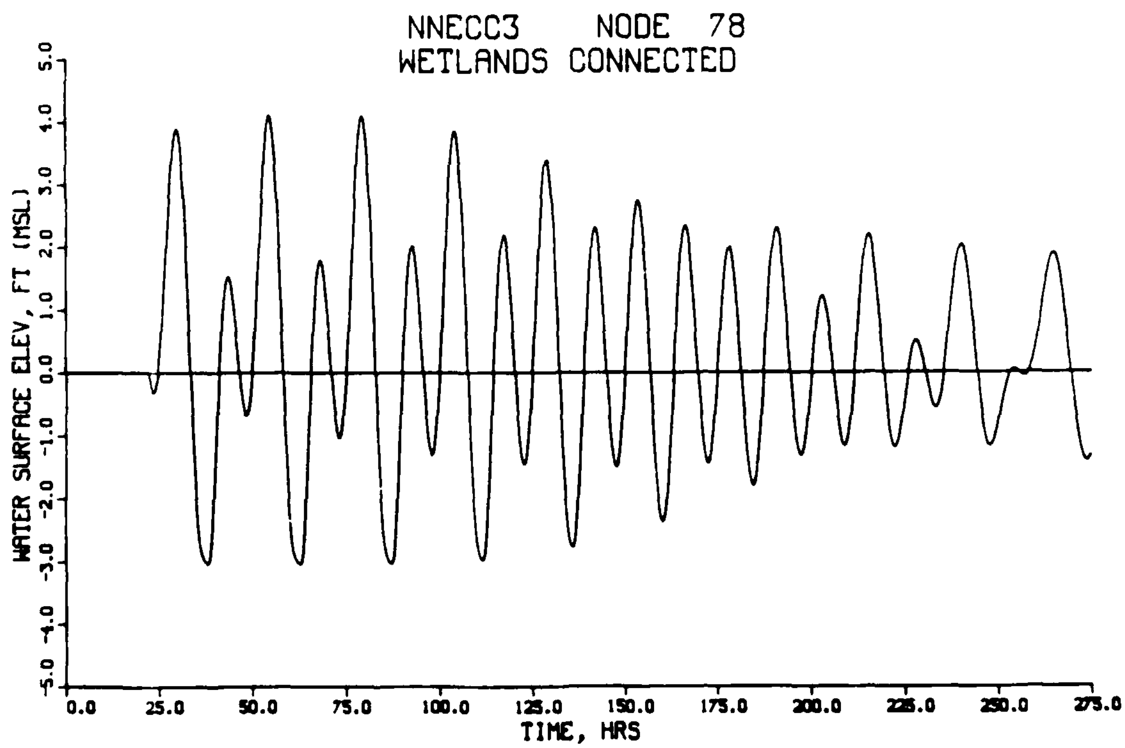


Figure G12. Tidal elevations in entrance channel under non-navigable entrance, by-pass connector channel to marina conditions

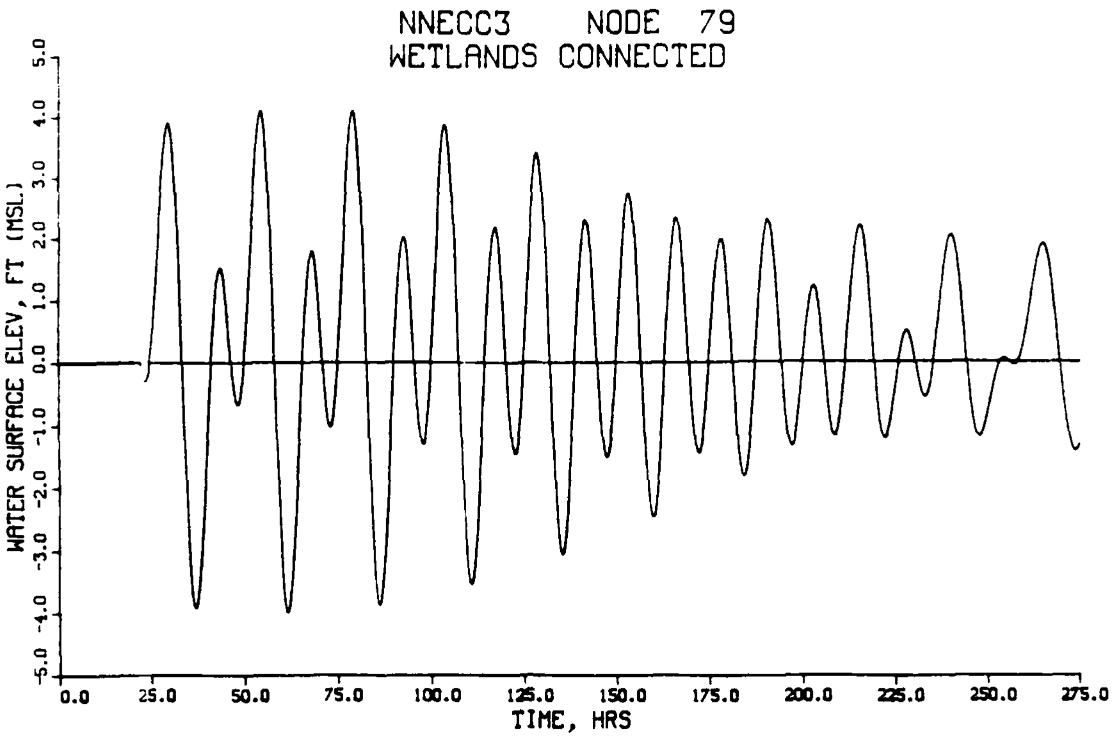


Figure G13. Tidal elevations in Pacific Ocean, driving non-navigable entrance, by-pass connector channel to marina conditions

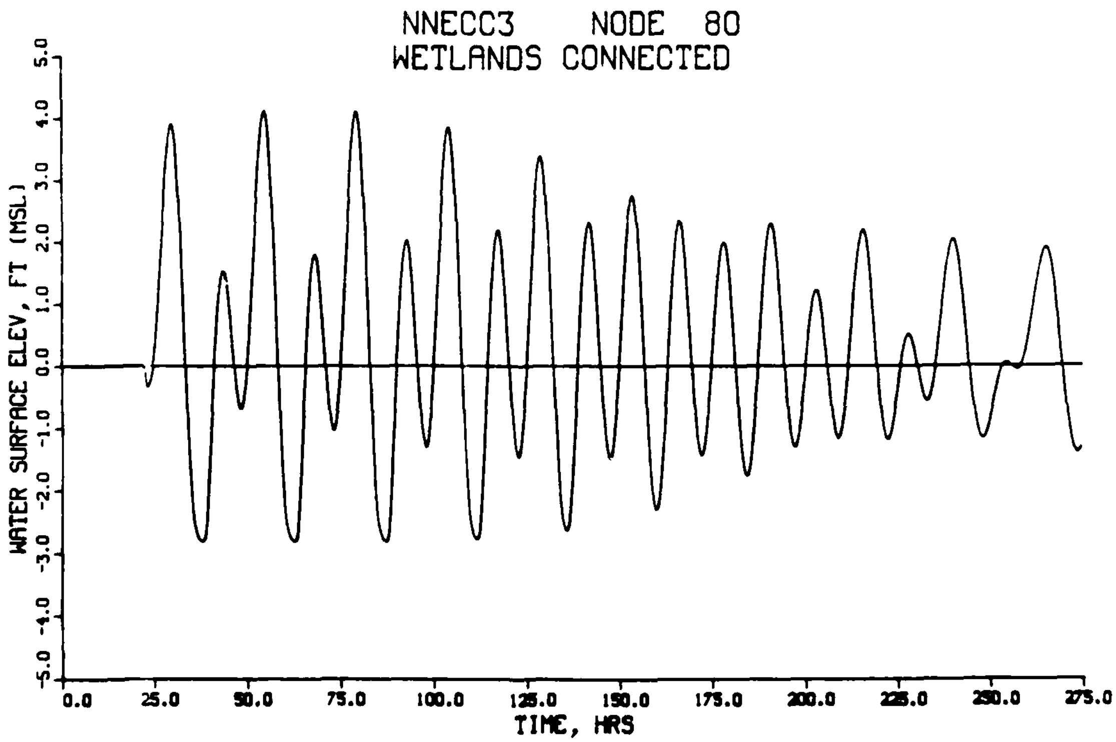


Figure G14. Tidal elevations in EGG-WFCC under non-navigable entrance, by-pass connector channel to marina conditions

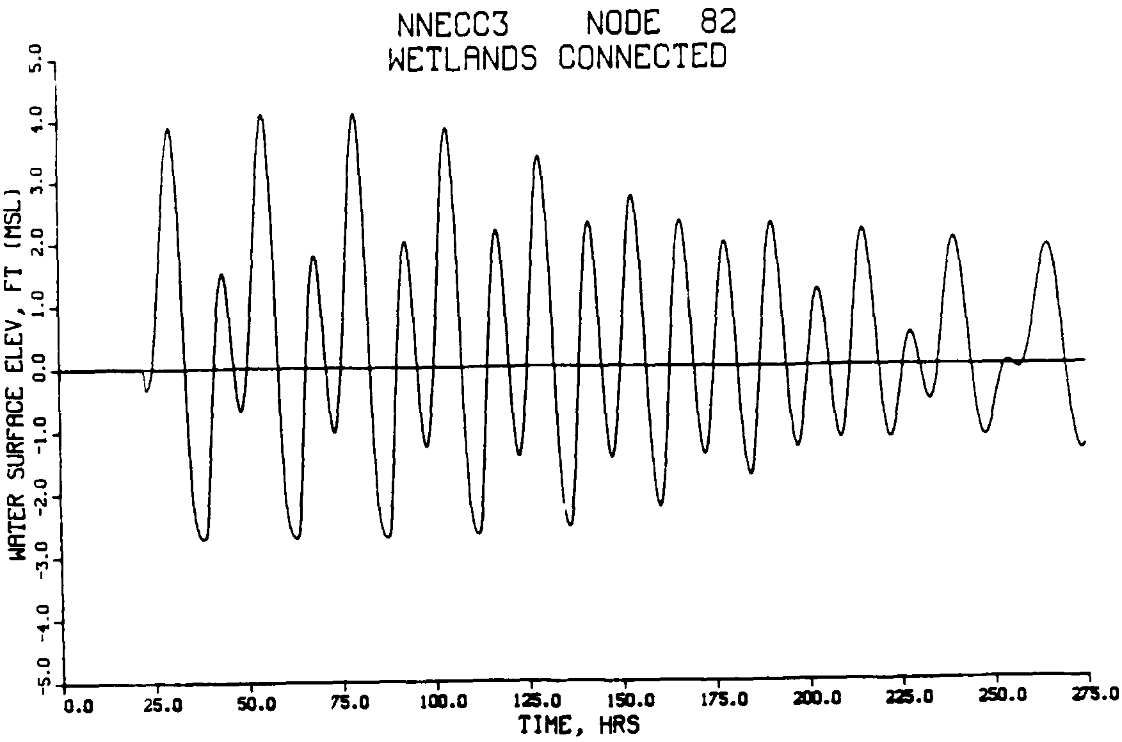


Figure G15. Tidal elevations in EGG-WFCC under non-navigable entrance, by-pass connector channel to marina conditions

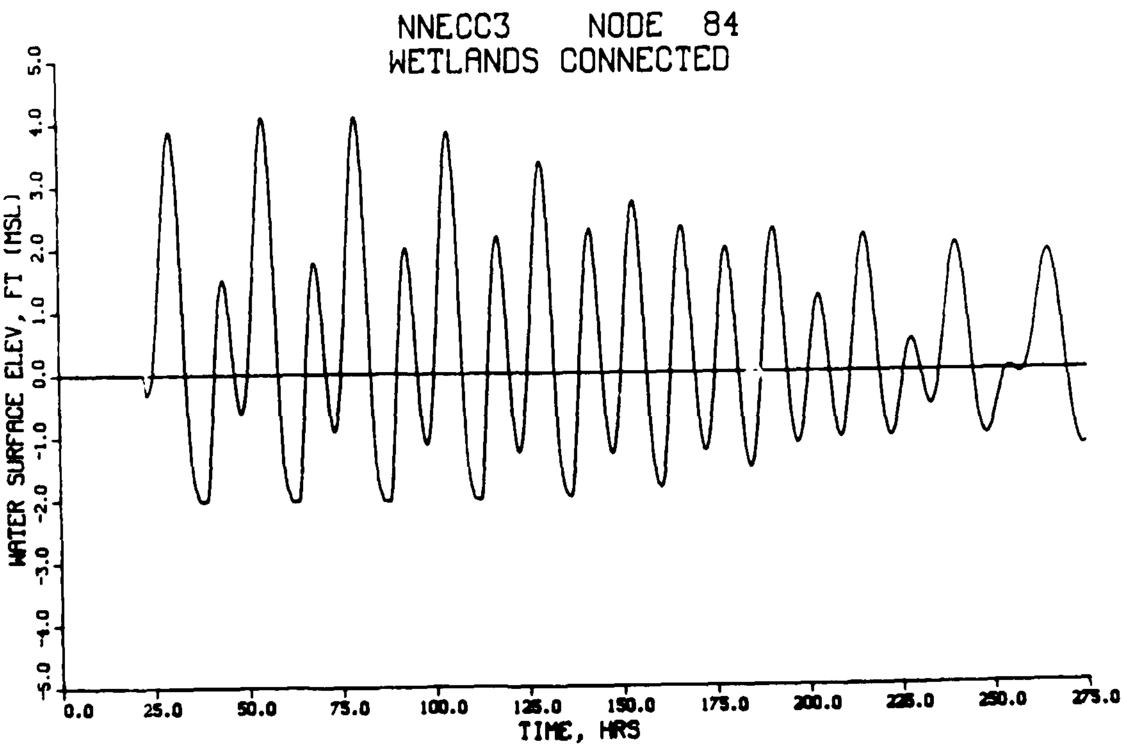


Figure G16. Tidal elevations in channel to proposed muted wetlands under non-navigable entrance, by-pass connector channel to marina conditions

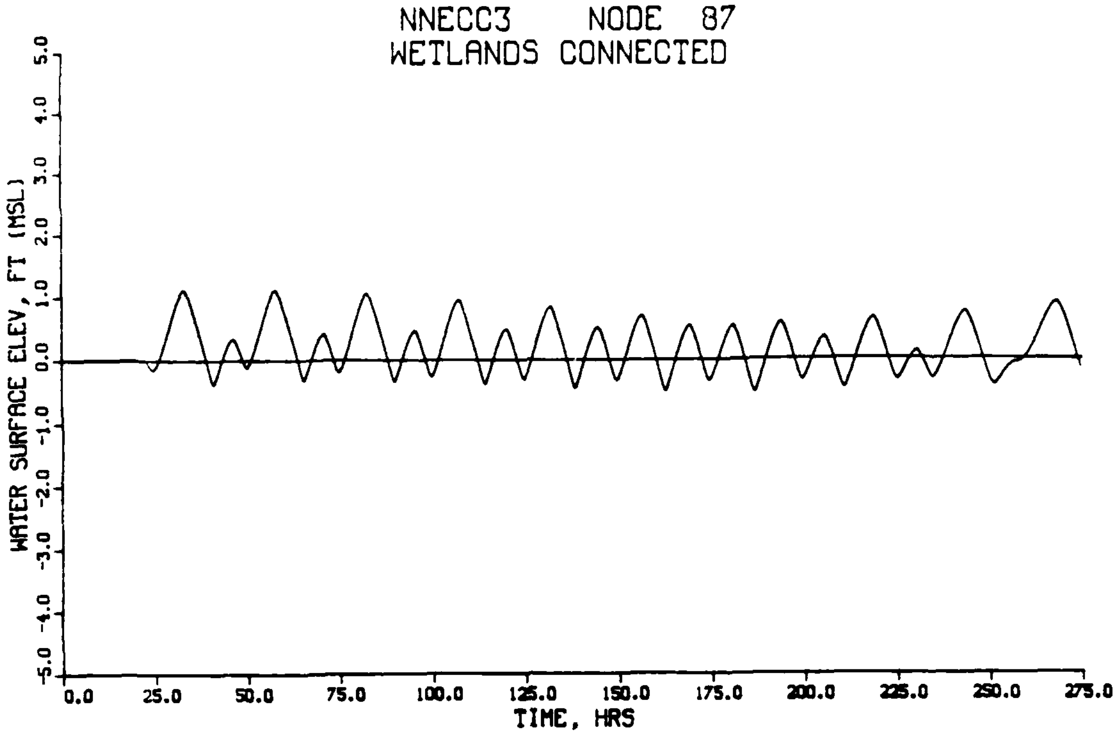


Figure G17. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance, by-pass connector channel to marina conditions

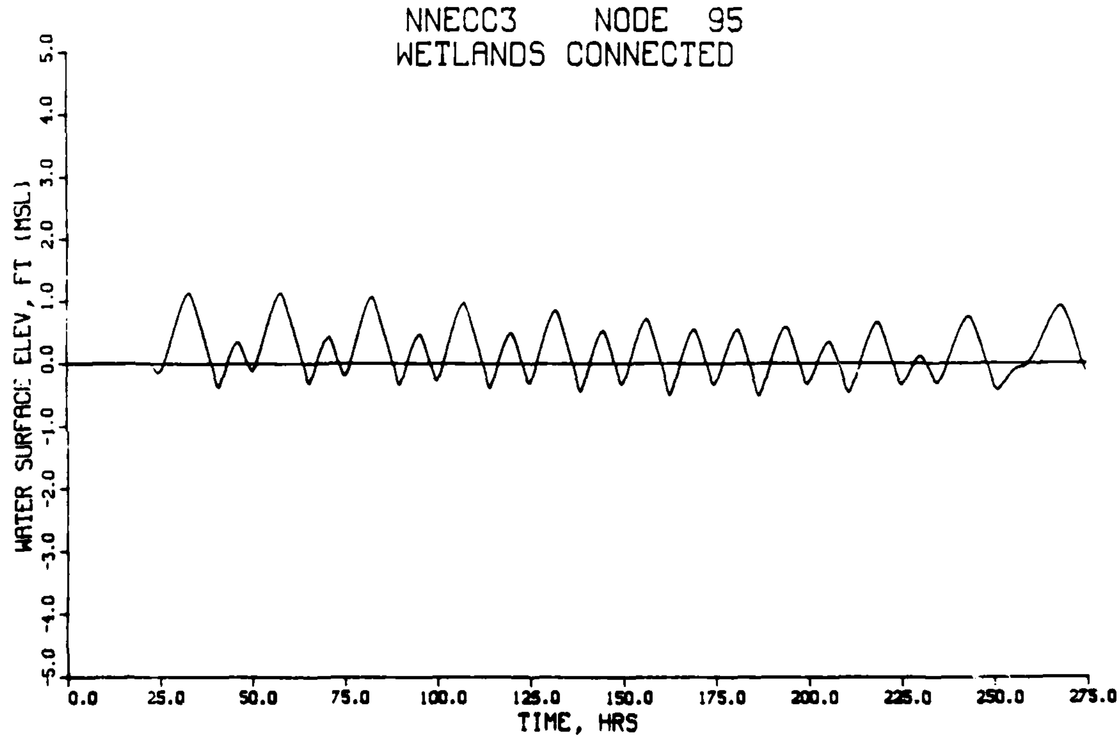


Figure G18. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance, by-pass connector channel to marina conditions

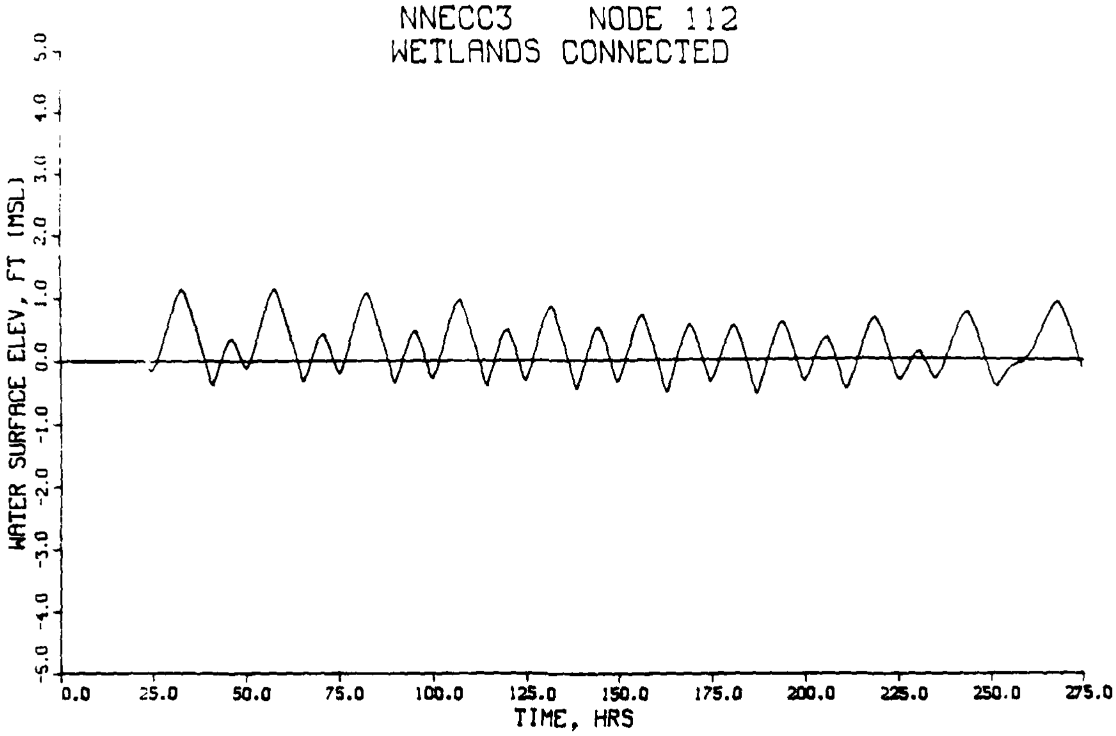


Figure G19. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance, by-pass connector channel to marina conditions

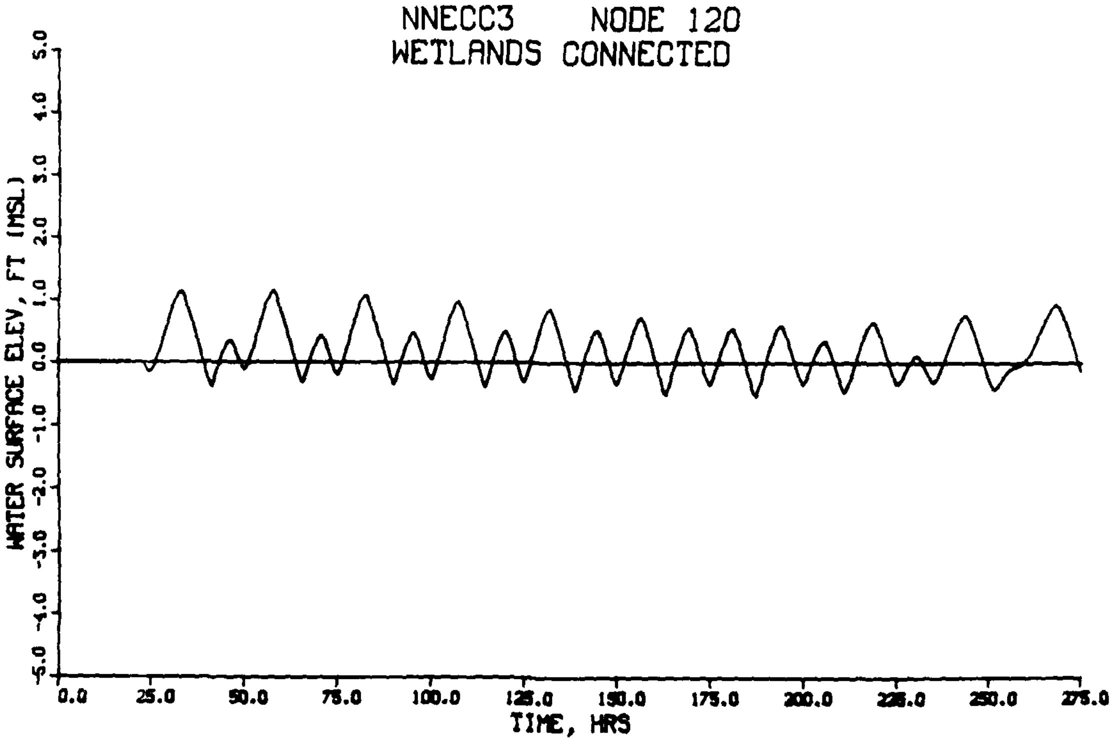


Figure G20. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance, by-pass connector channel to marina conditions

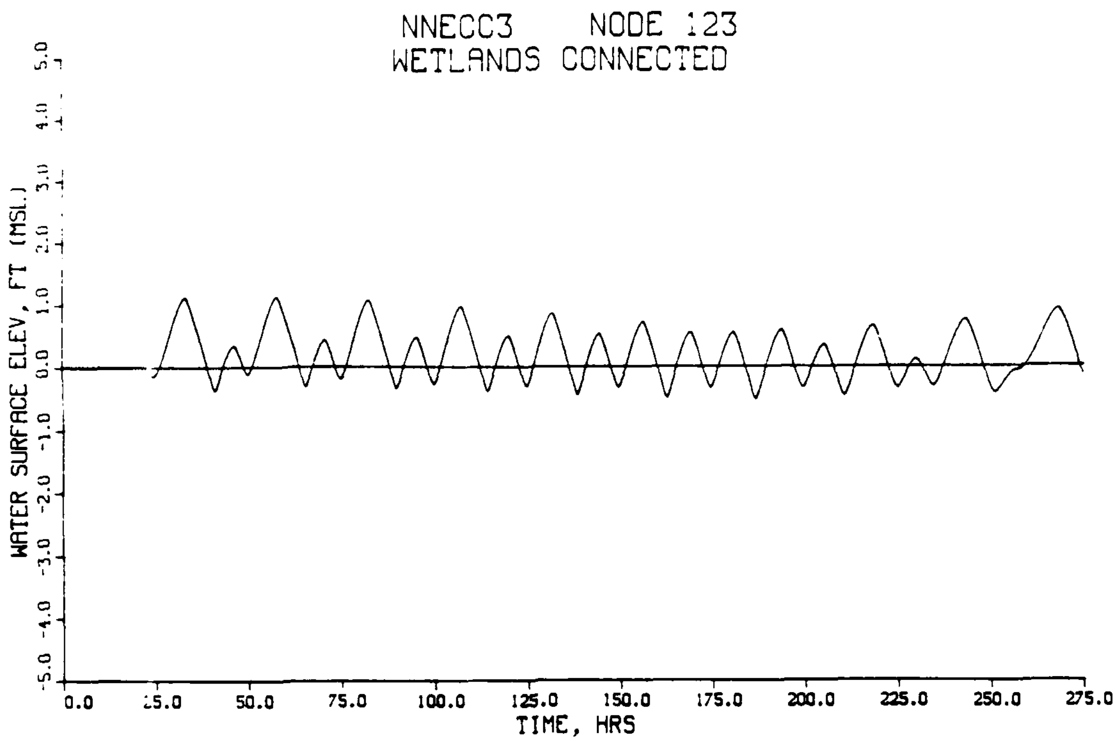


Figure G21. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance, by-pass connector channel to marina conditions

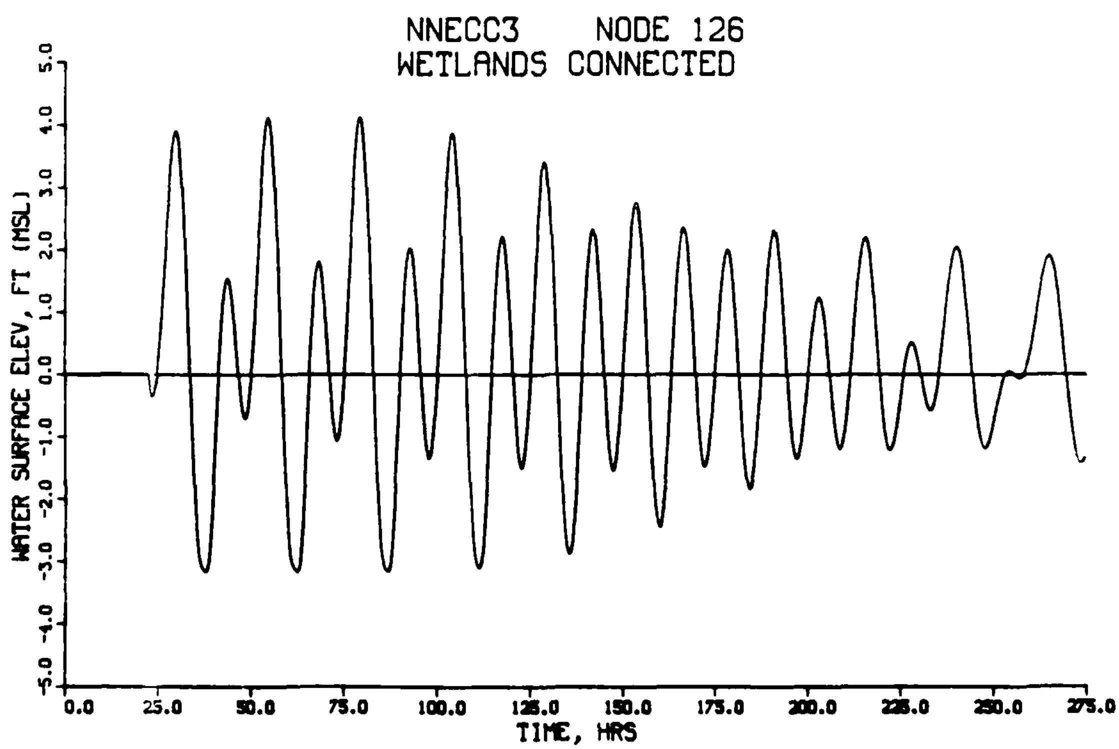


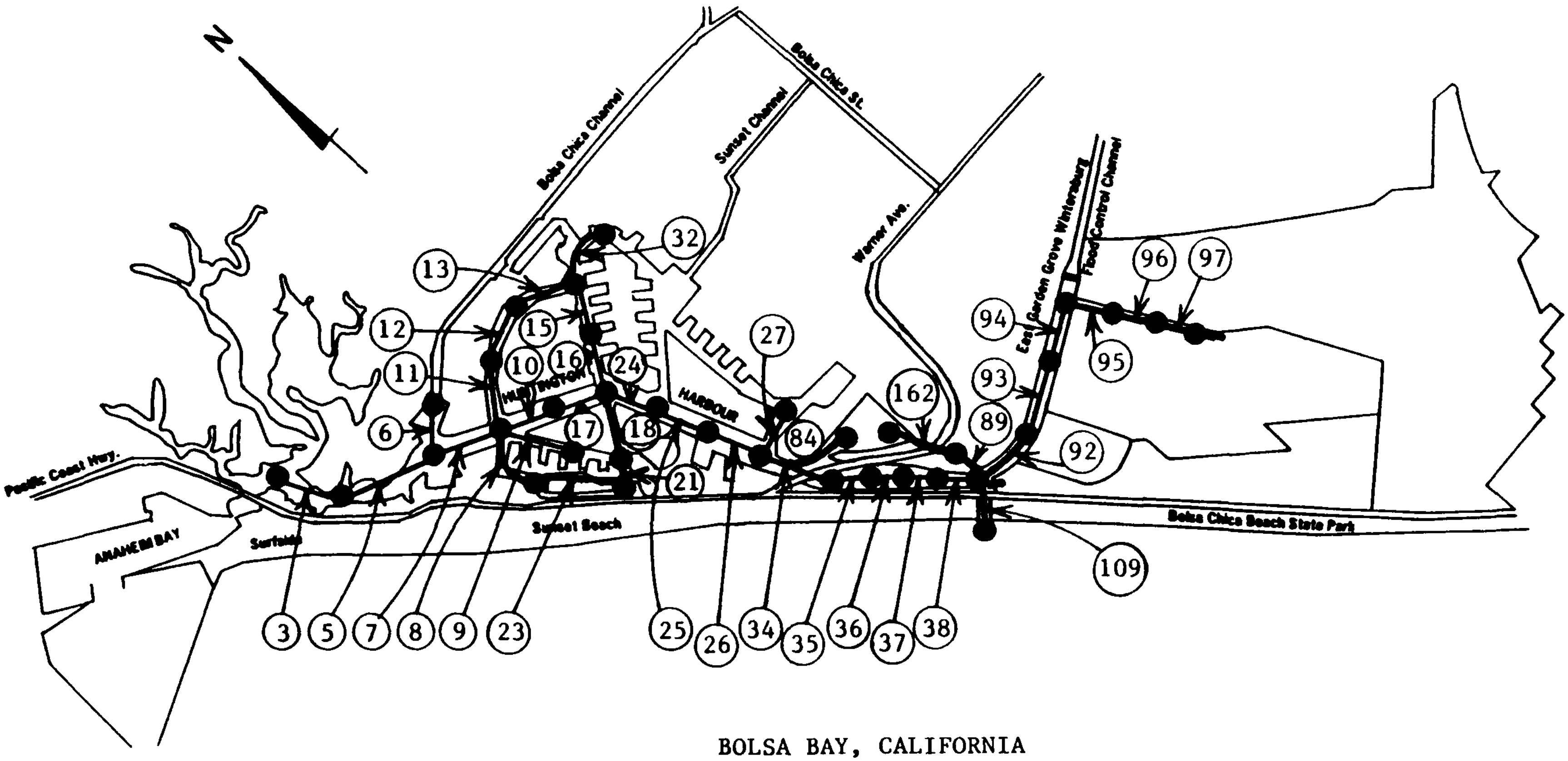
Figure G22. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance, by-pass connector channel to marina conditions

APPENDIX H:

NNECC3

NON-NAVIGABLE ENTRANCE CHANNEL
AND
BY-PASS CONNECTOR CHANNEL TO MARINA

AVERAGE CHANNEL VELOCITIES



BOLSA BAY, CALIFORNIA

NNECC3
Location of links for displaying average channel velocities
under non-navigable entrance channel and by-pass connector channel to marina conditions

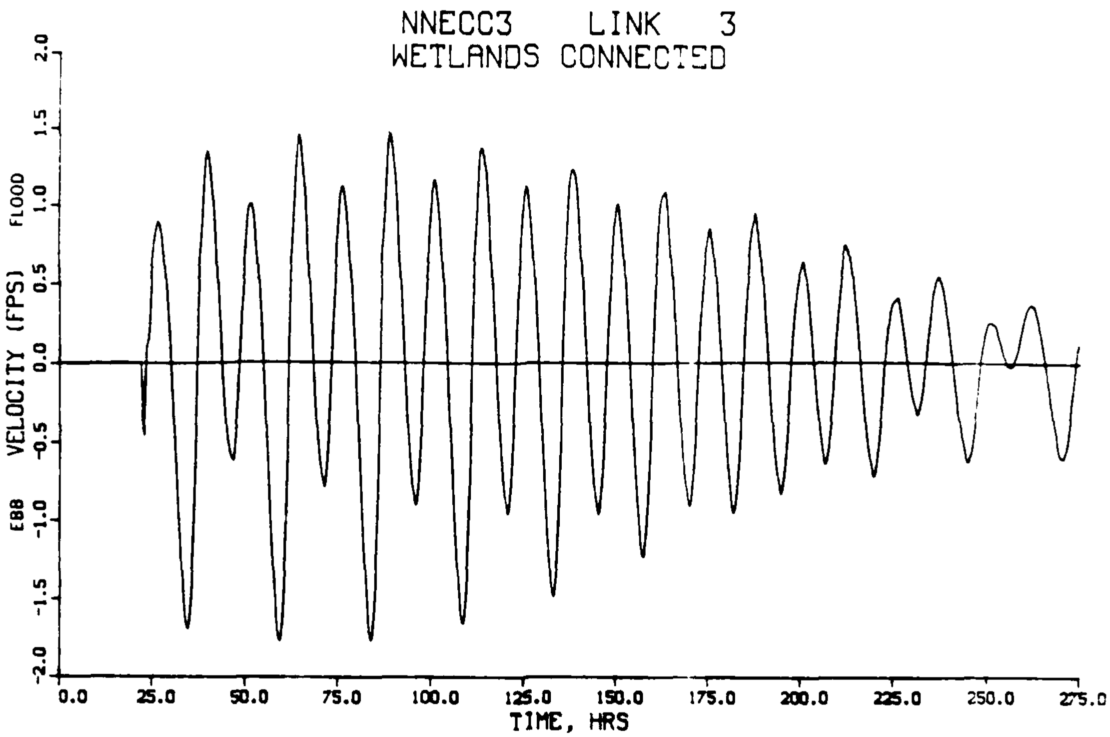


Figure H1. Average channel velocities in Huntington Harbour under non-navigable entrance, by-pass connector channel to marina conditions

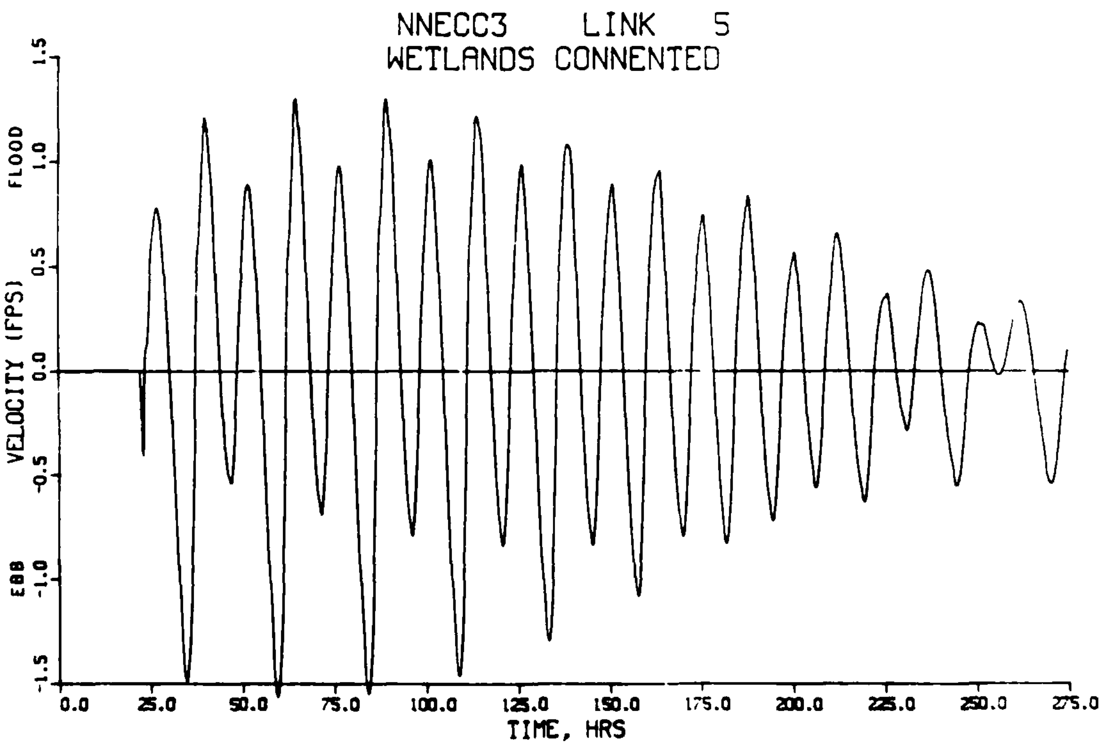


Figure H2. Average channel velocities in Huntington Harbour under non-navigable entrance, by-pass connector channel to marina conditions

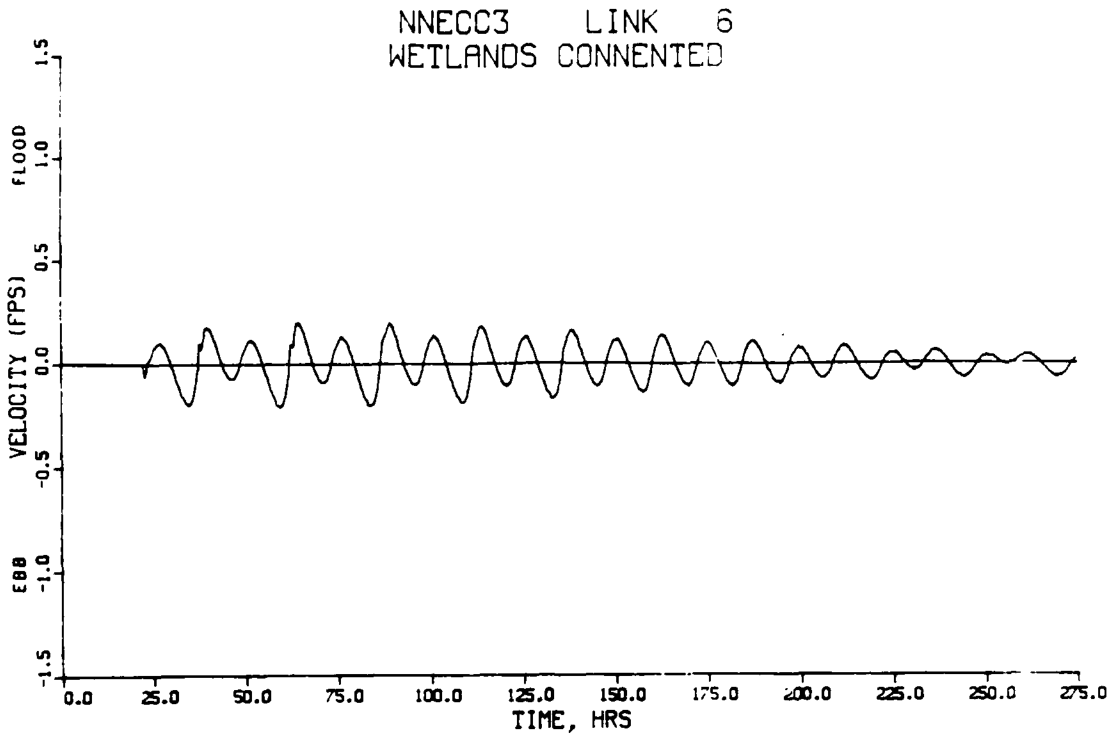


Figure H3. Average channel velocities in Huntington Harbour under non-navigable entrance, by-pass connector channel to marina conditions

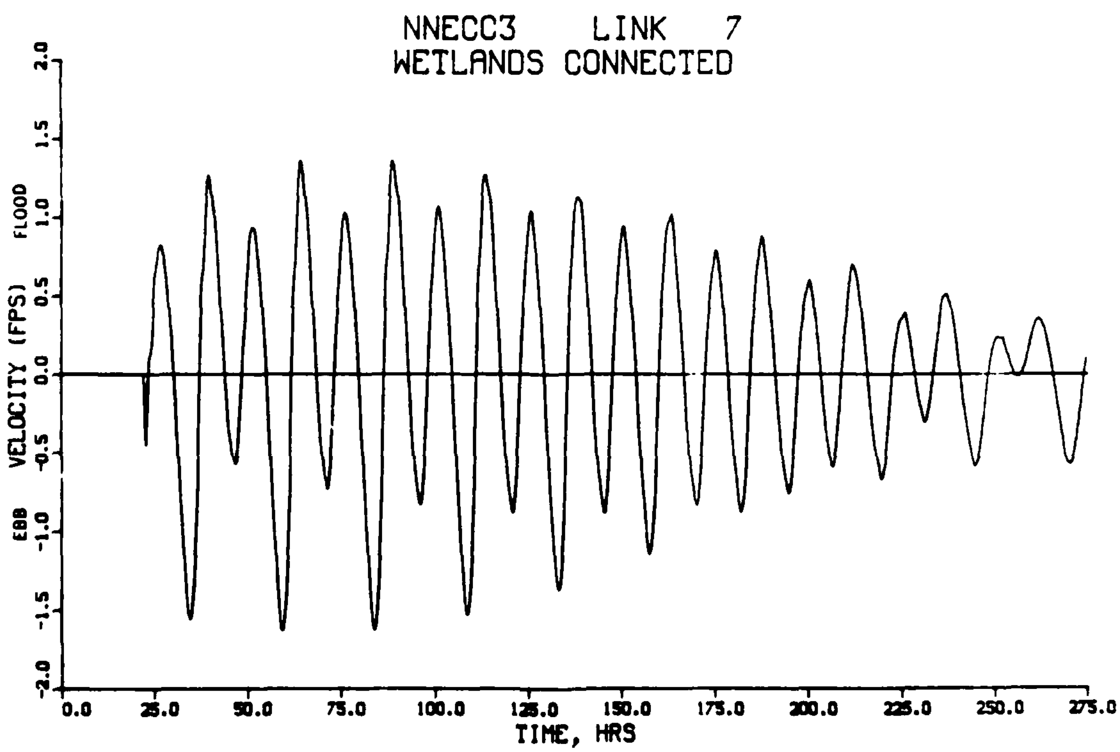


Figure H4. Average channel velocities in Huntington Harbour under non-navigable entrance, by-pass connector channel to marina conditions

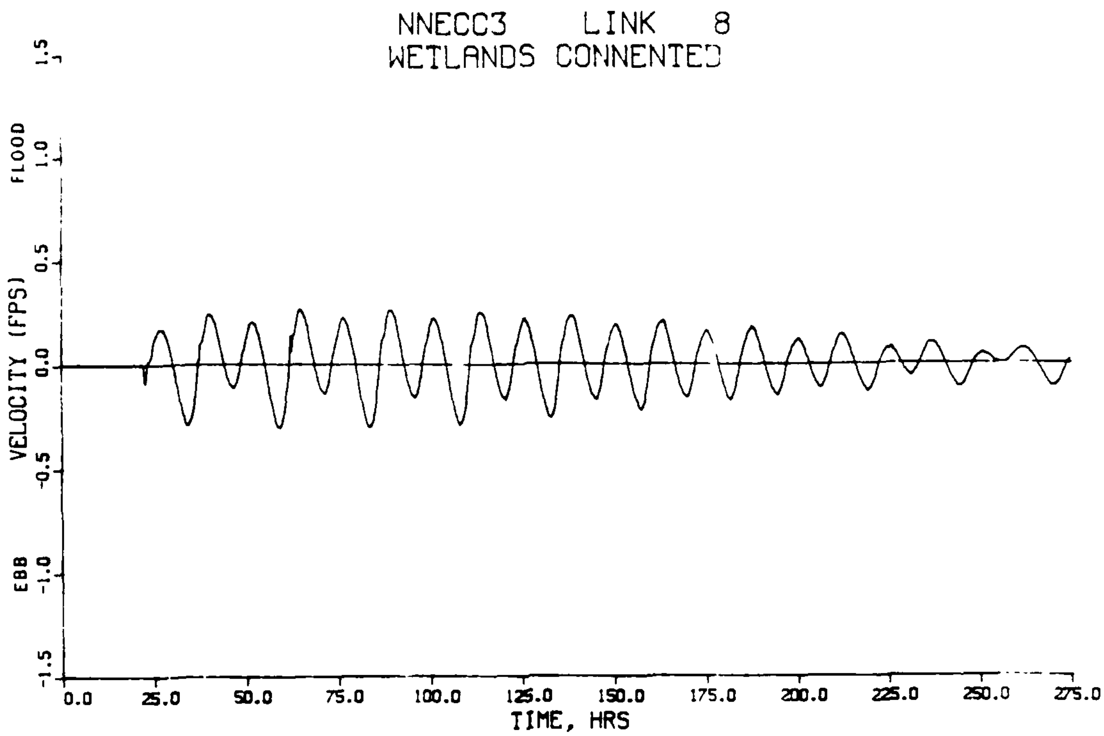


Figure H5. Average channel velocities in Huntington Harbour under non-navigable entrance, by-pass connector channel to marina conditions

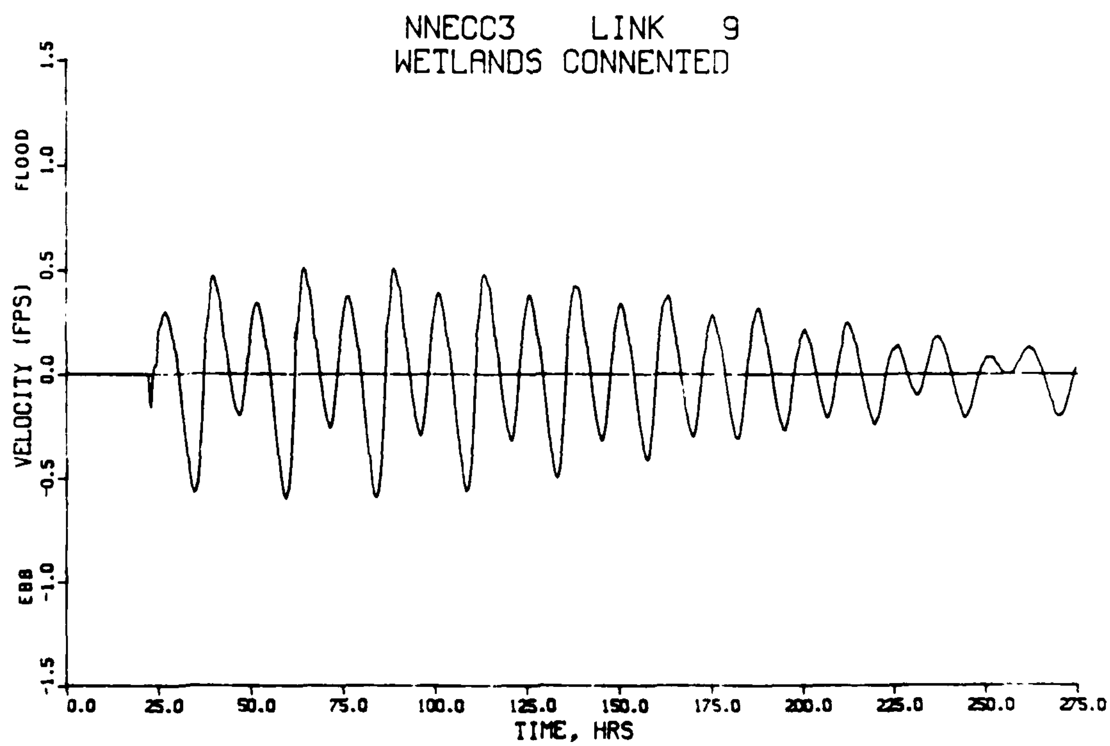


Figure H6. Average channel velocities in Huntington Harbour under non-navigable entrance, by-pass connector channel to marina conditions

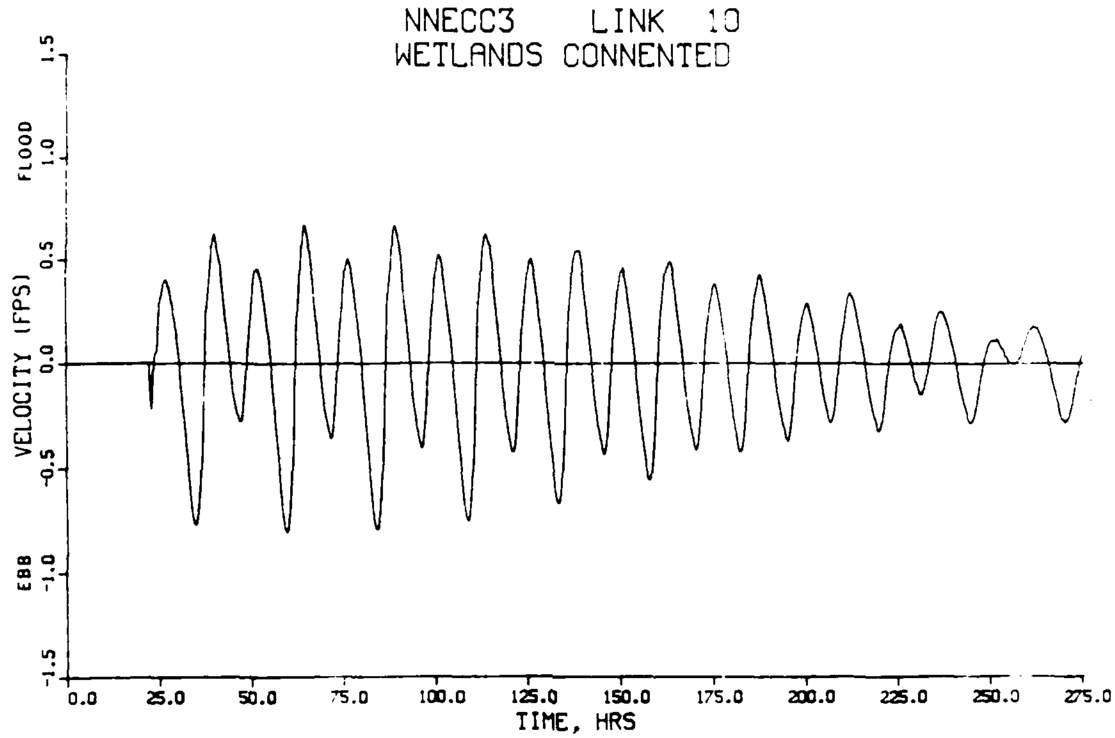


Figure H7. Average channel velocities in Huntington Harbour under non-navigable entrance, by-pass connector channel to marina conditions

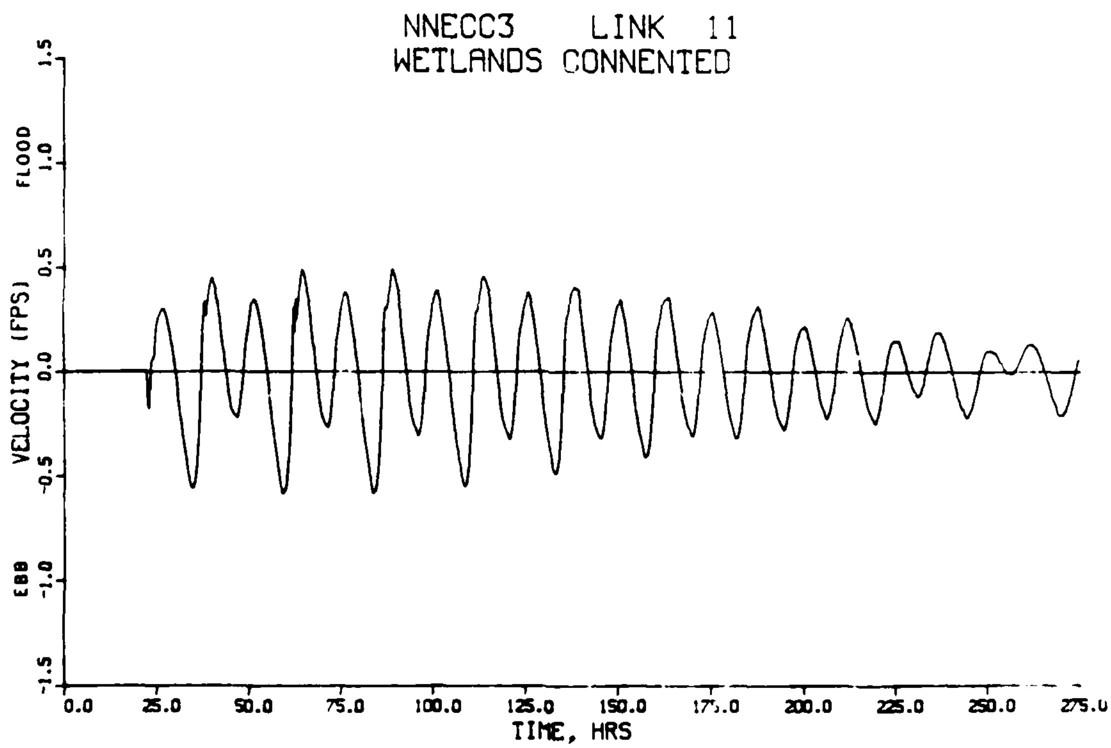


Figure H8. Average channel velocities in Huntington Harbour under non-navigable entrance, by-pass connector channel to marina conditions

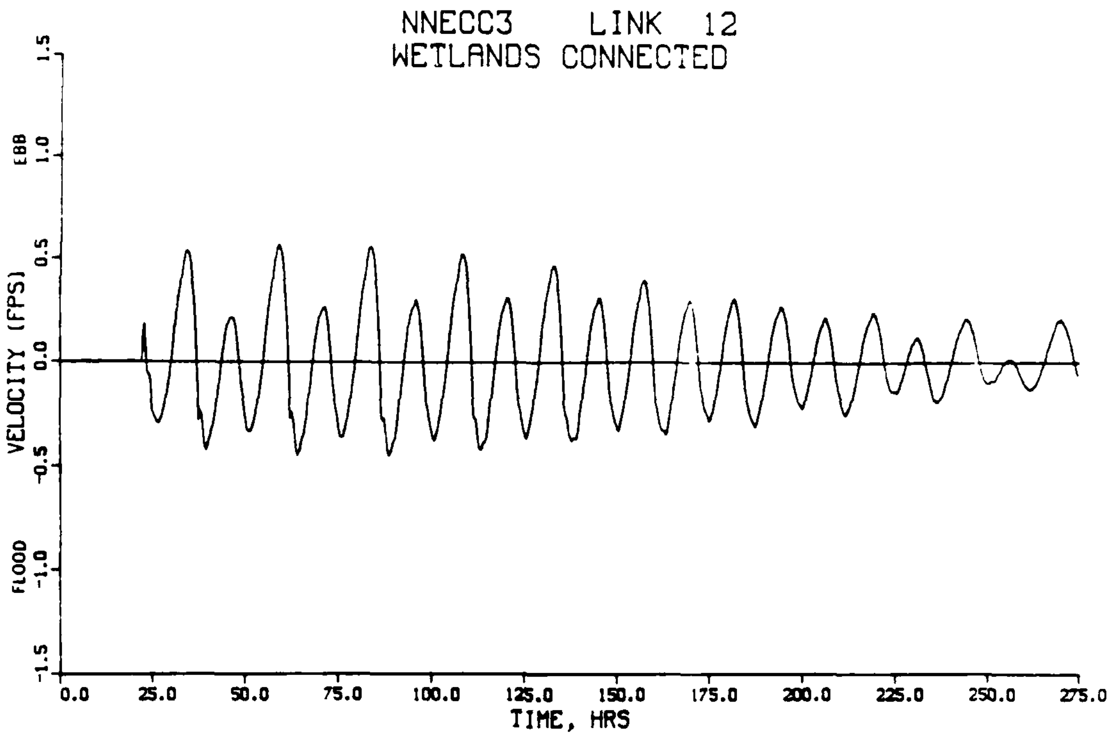


Figure H9. Average channel velocities in Huntington Harbour under non-navigable entrance, by-pass connector channel to marina conditions

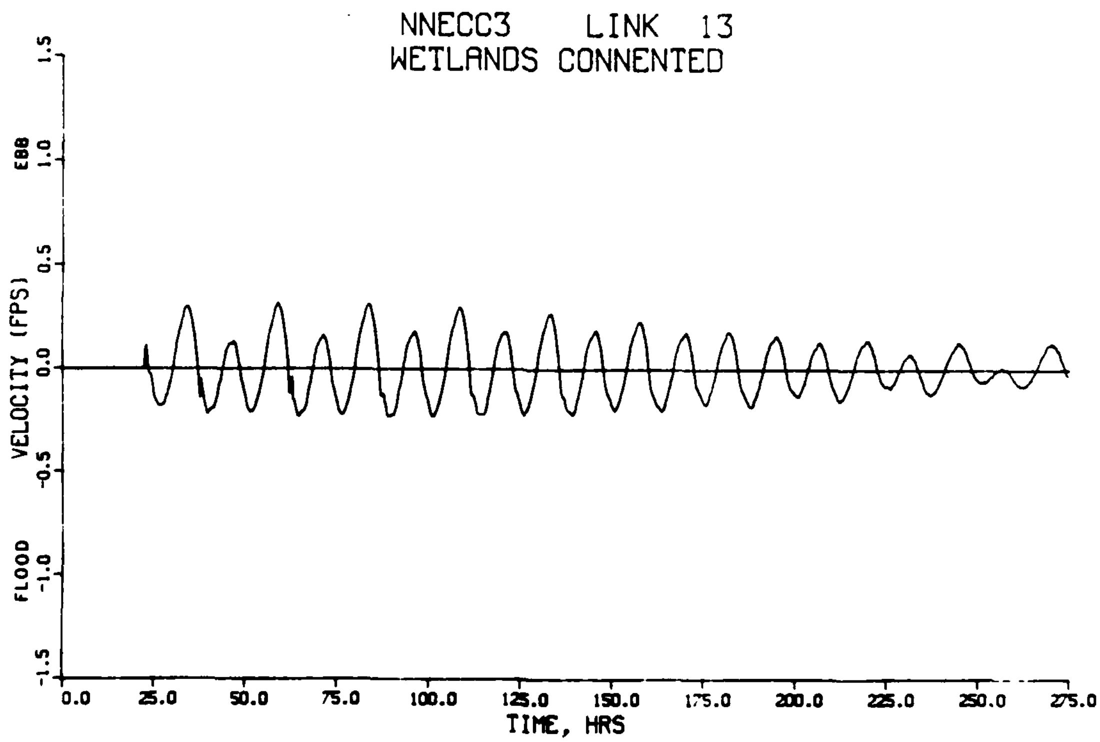


Figure H10. Average channel velocities in Huntington Harbour under non-navigable entrance, by-pass connector channel to marina conditions

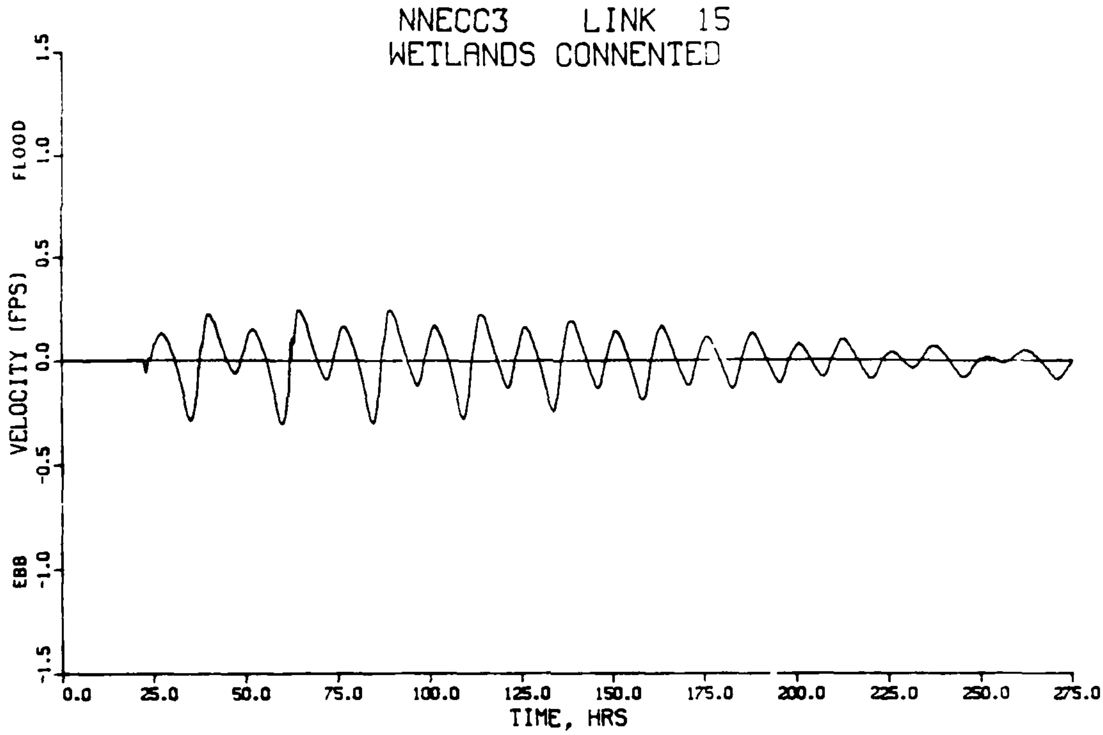


Figure H11. Average channel velocities in Huntington Harbour under non-navigable entrance, by-pass connector channel to marina conditions

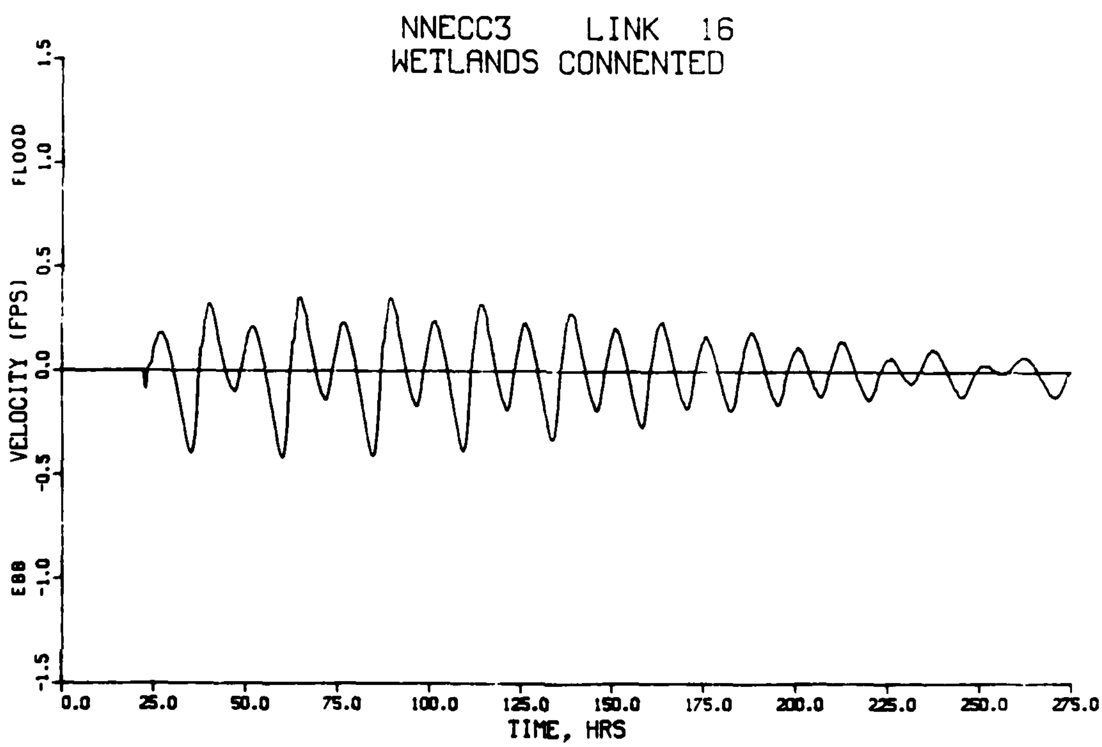


Figure H12. Average channel velocities in Huntington Harbour under non-navigable entrance, by-pass connector channel to marina conditions

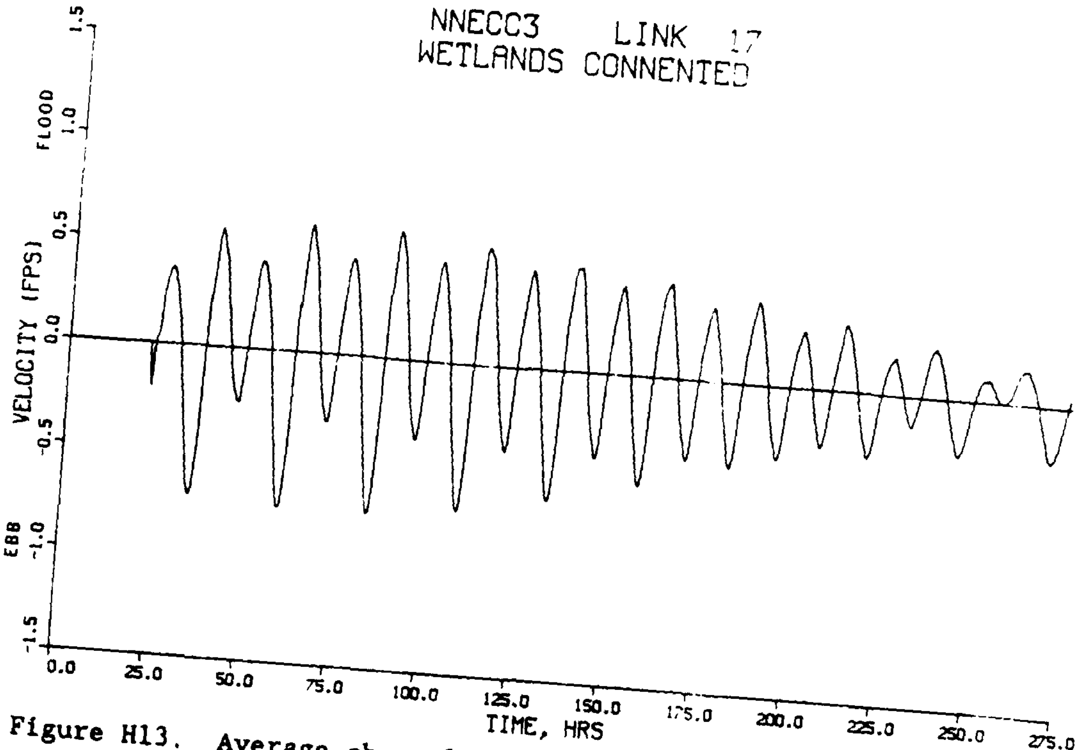


Figure H13. Average channel velocities in Huntington Harbour under non-navigable entrance, by-pass connector channel to marina conditions

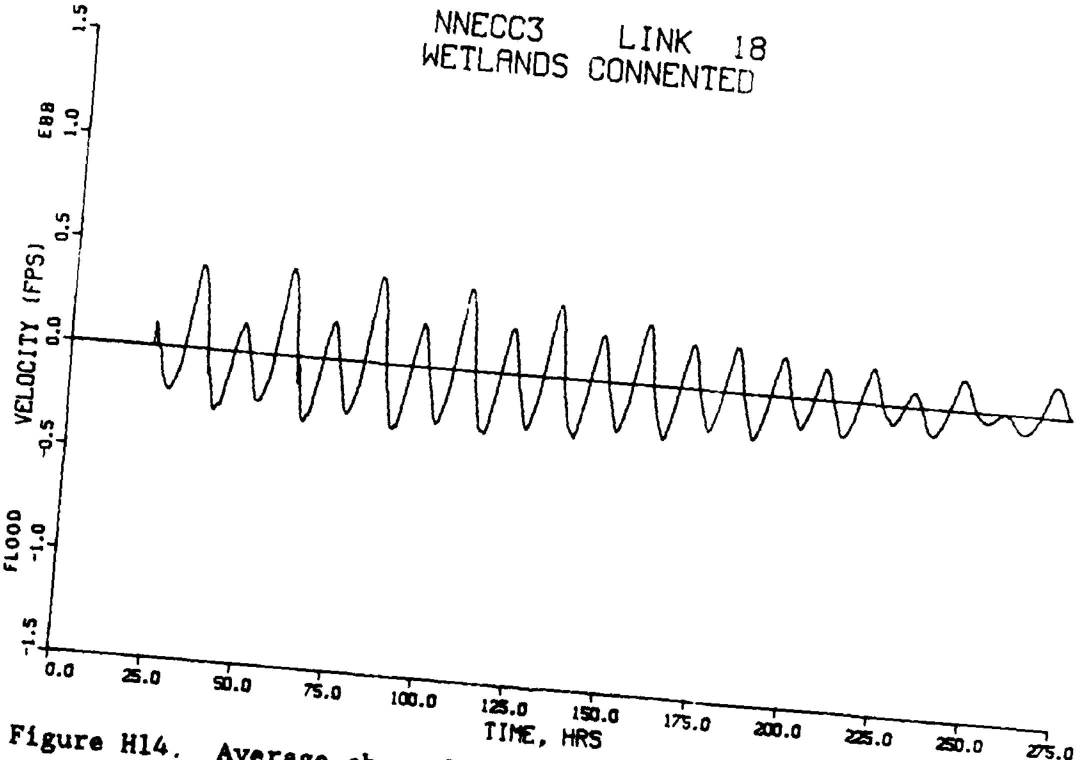


Figure H14. Average channel velocities in Huntington Harbour under non-navigable entrance, by-pass connector channel to marina conditions

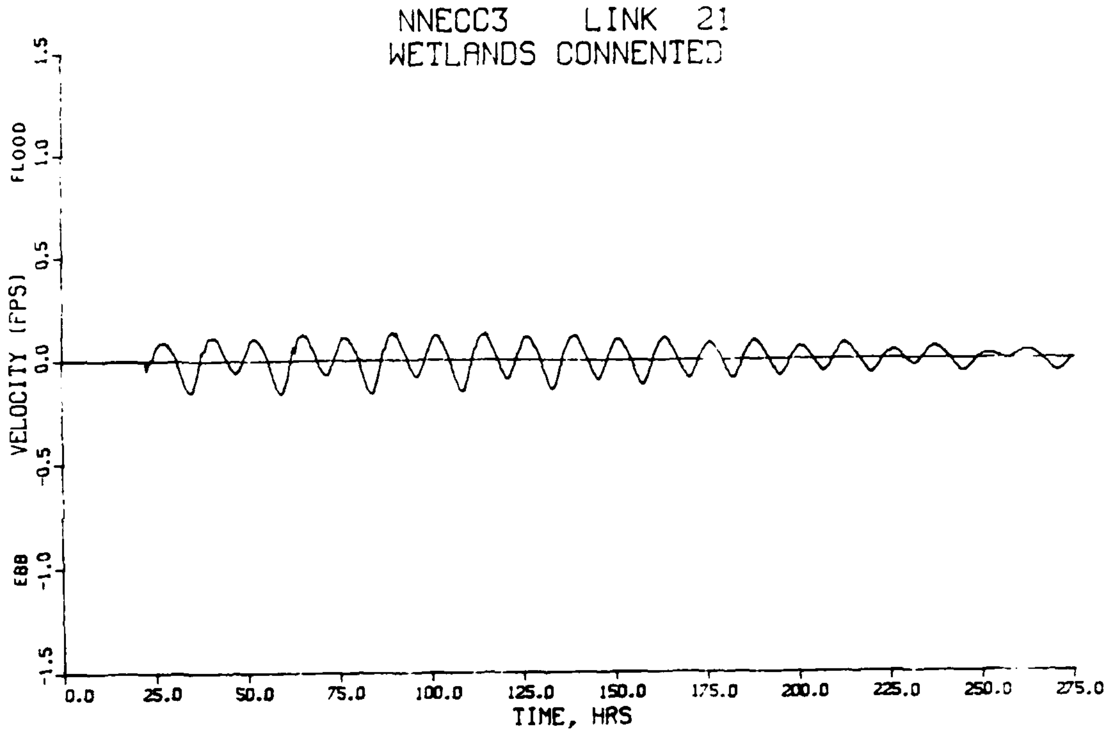


Figure H15. Average channel velocities in Huntington Harbour under non-navigable entrance, by-pass connector channel to marina conditions

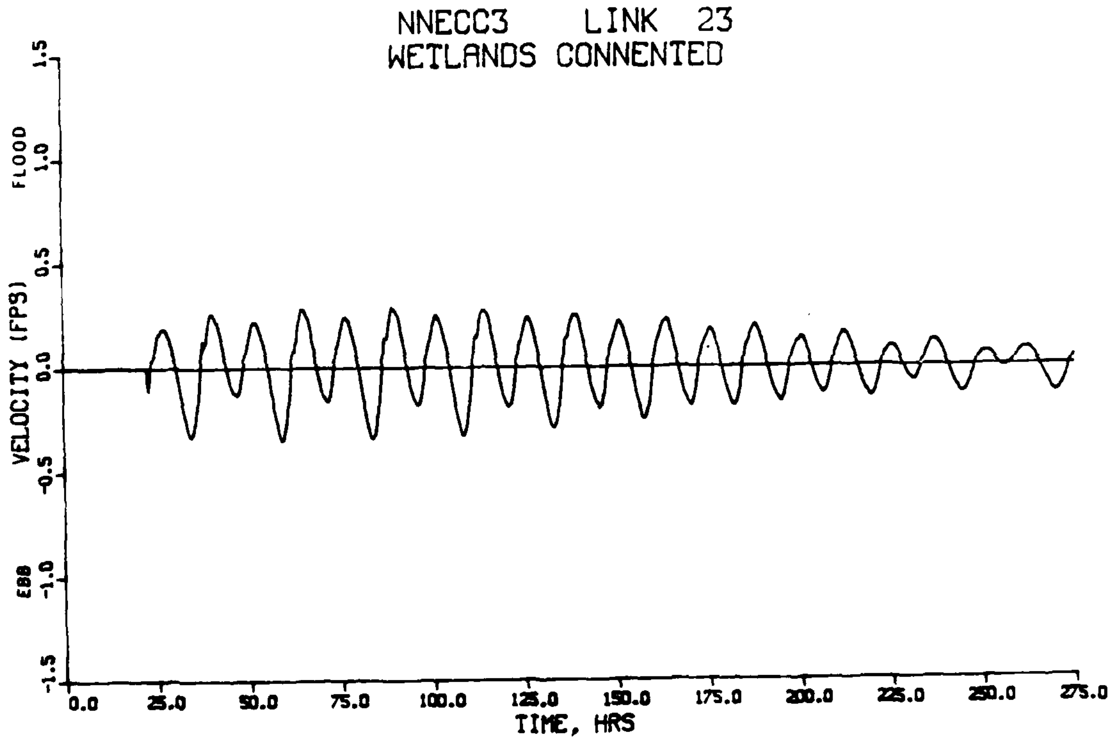


Figure H16. Average channel velocities in Huntington Harbour under non-navigable entrance, by-pass connector channel to marina conditions

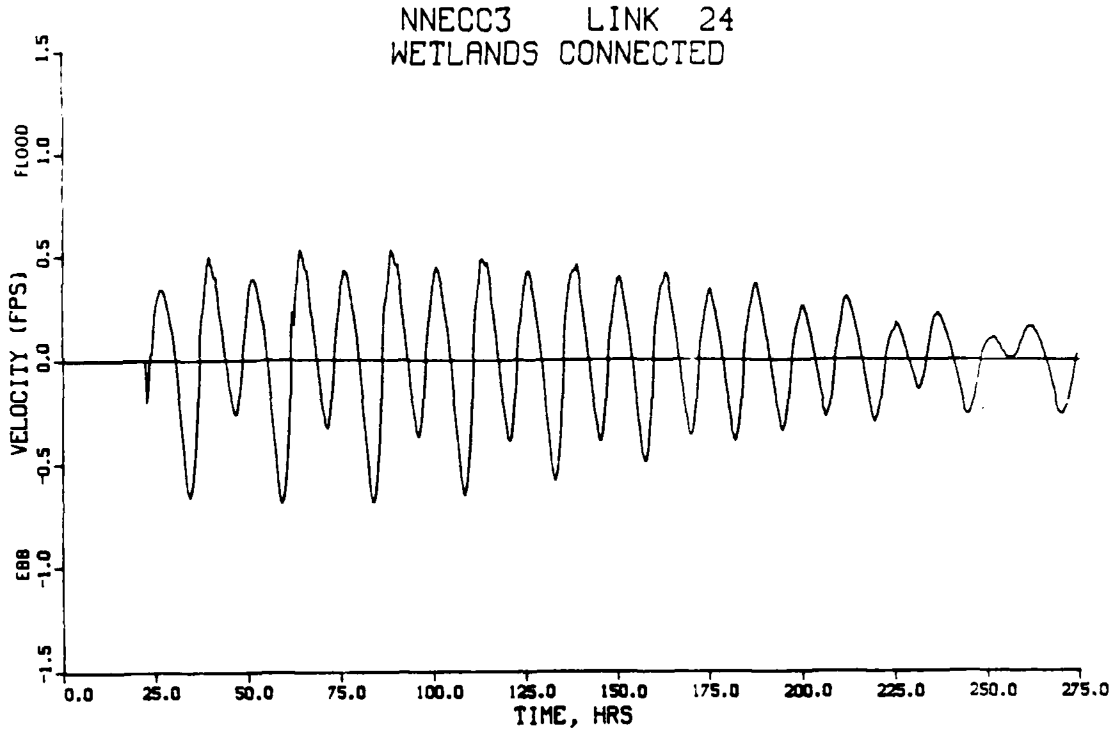


Figure H17. Average channel velocities in Huntington Harbour under non-navigable entrance, by-pass connector channel to marina conditions

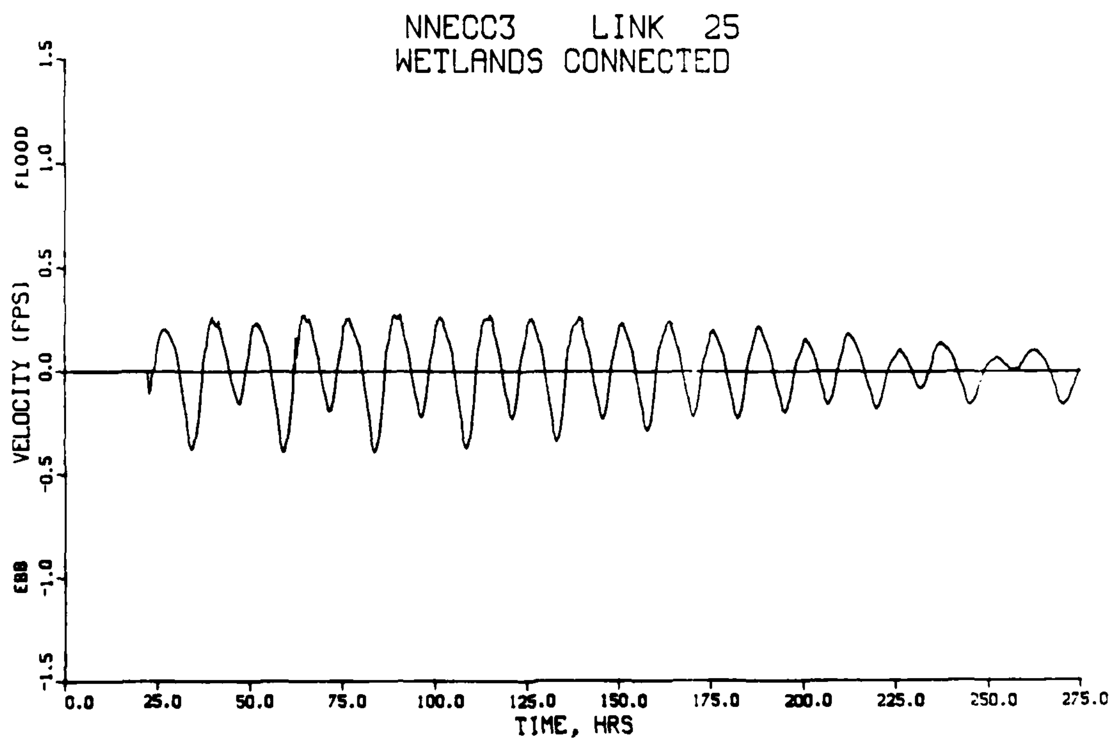


Figure H18. Average channel velocities in Huntington Harbour under non-navigable entrance, by-pass connector channel to marina conditions

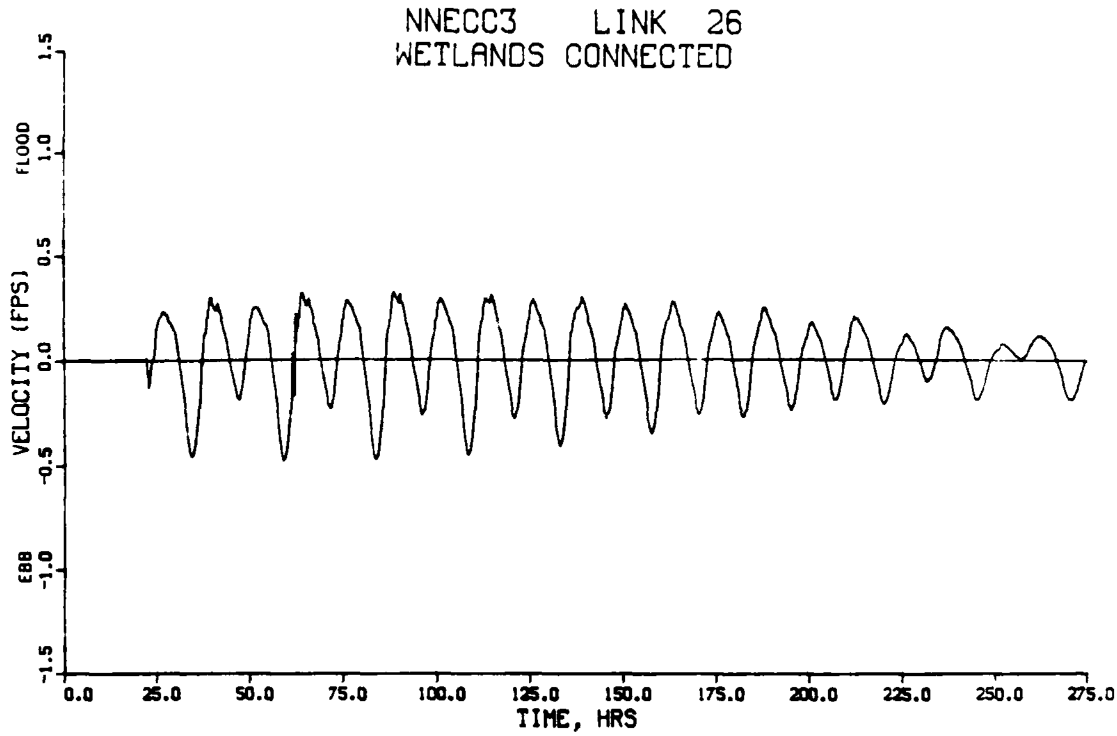


Figure H19. Average channel velocities in Huntington Harbour under non-navigable entrance, by-pass connector channel to marina conditions

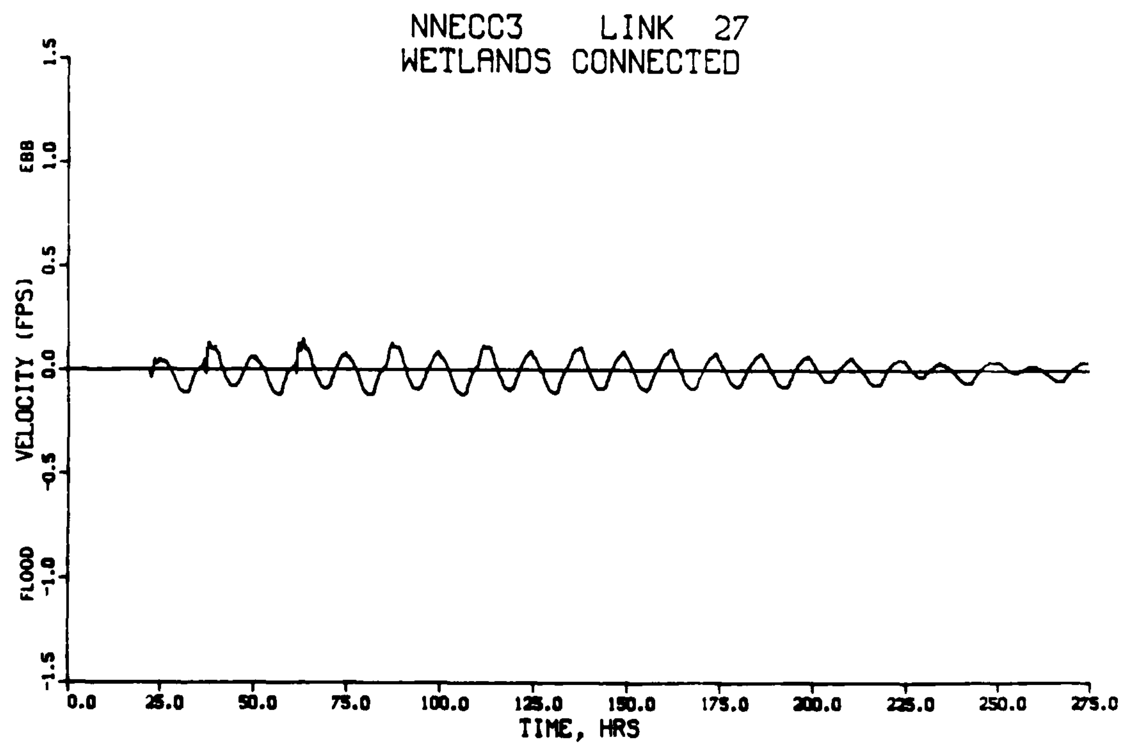


Figure H20. Average channel velocities in Huntington Harbour under non-navigable entrance, by-pass connector channel to marina conditions

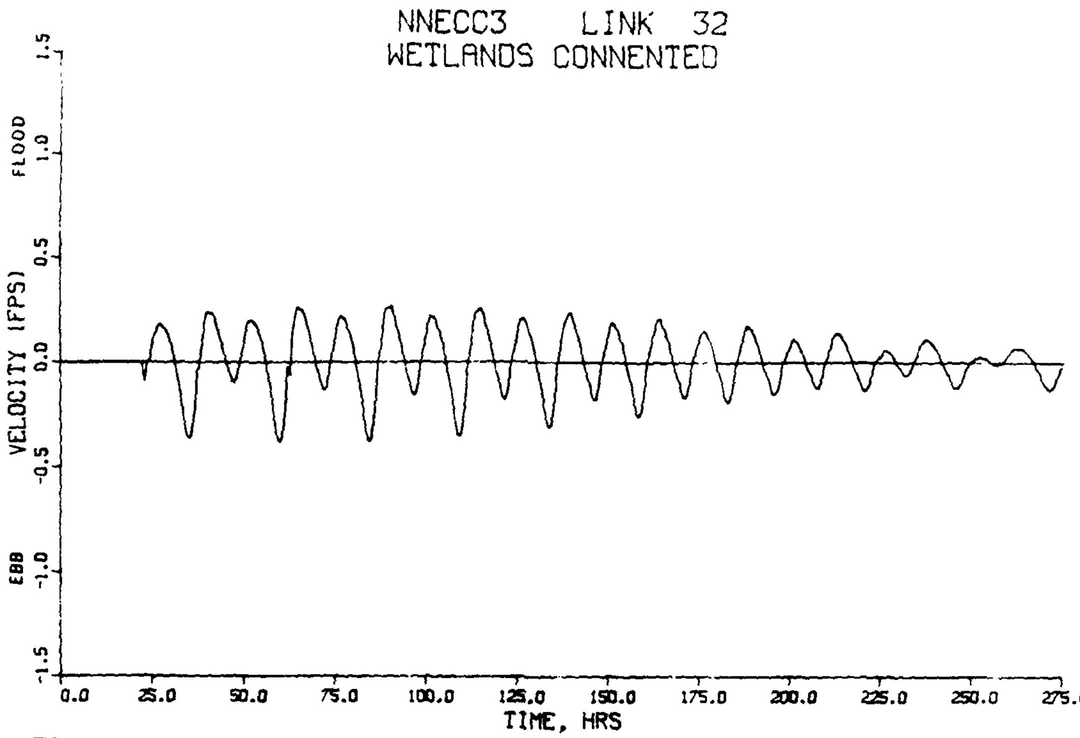


Figure H21. Average channel velocities in Huntington Harbour under non-navigable entrance, by-pass connector channel to marina conditions

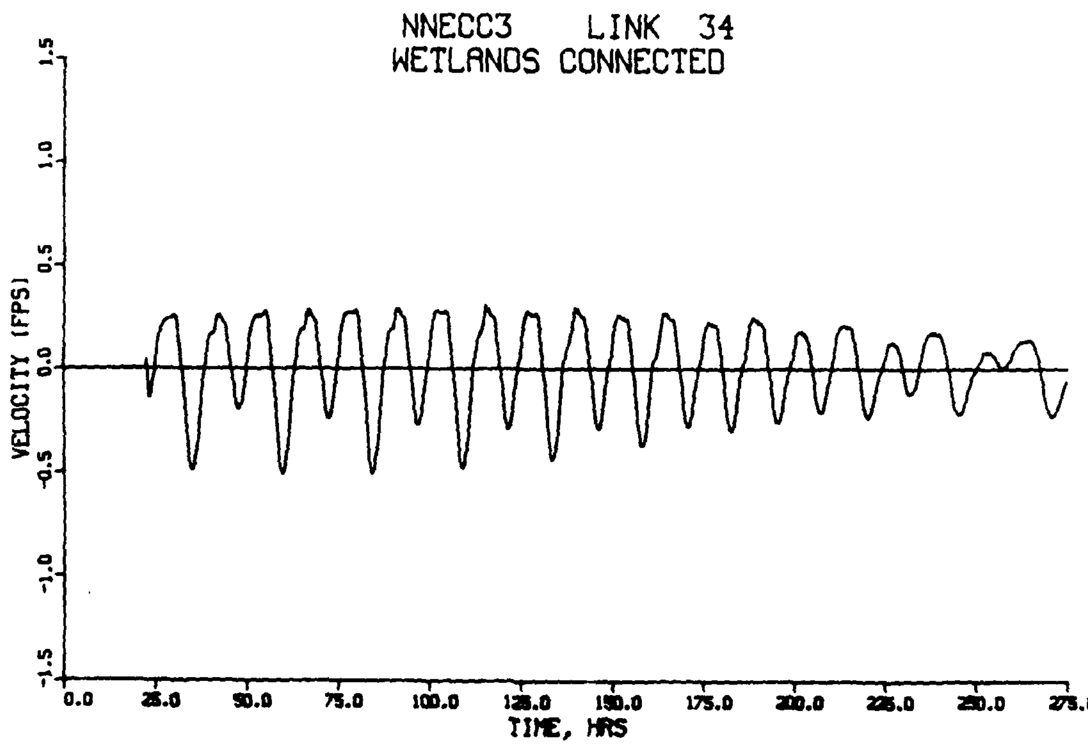


Figure H22. Average channel velocities at previous Warner Avenue under non-navigable entrance, by-pass connector channel to marina conditions

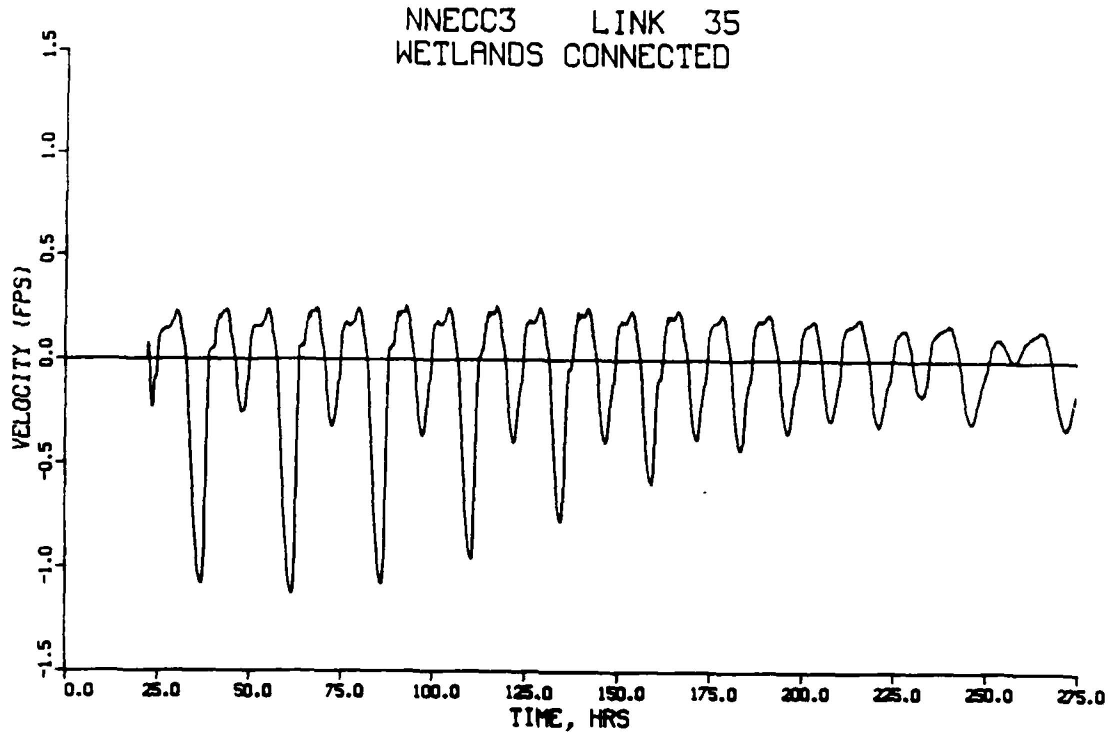


Figure H23. Average channel velocities in Outer Bolsa Bay under non-navigable entrance, by-pass connector channel to marina conditions

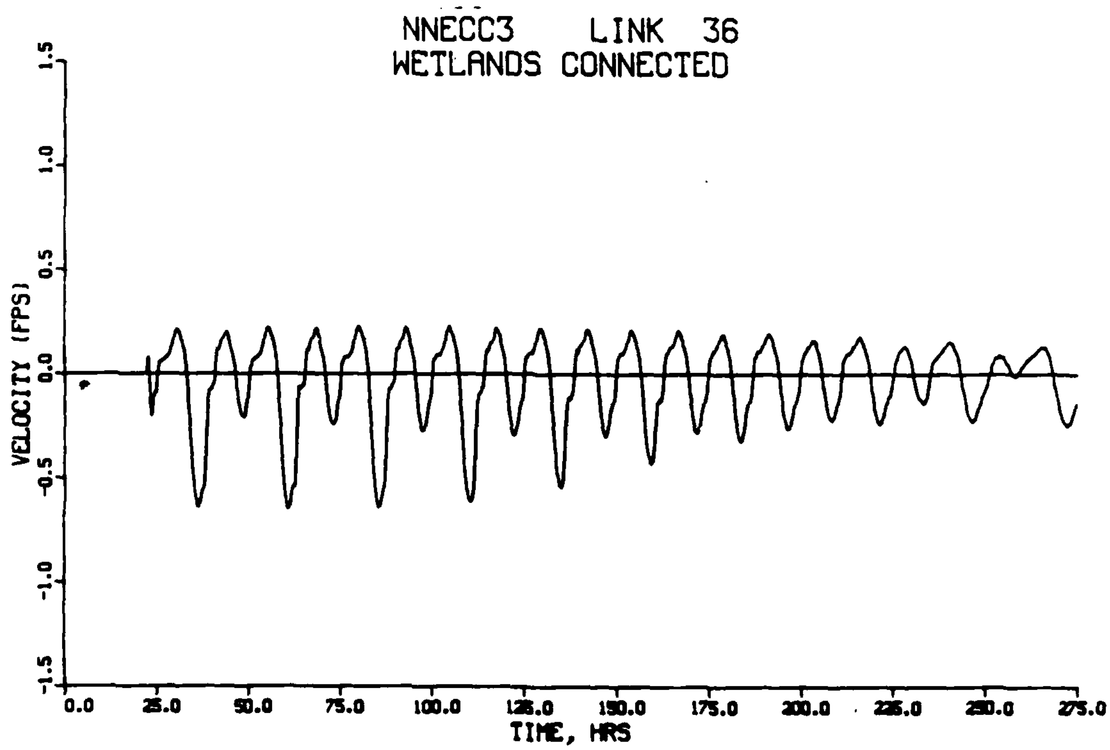


Figure H24. Average channel velocities in Outer Bolsa Bay under non-navigable entrance, by-pass connector channel to marina conditions

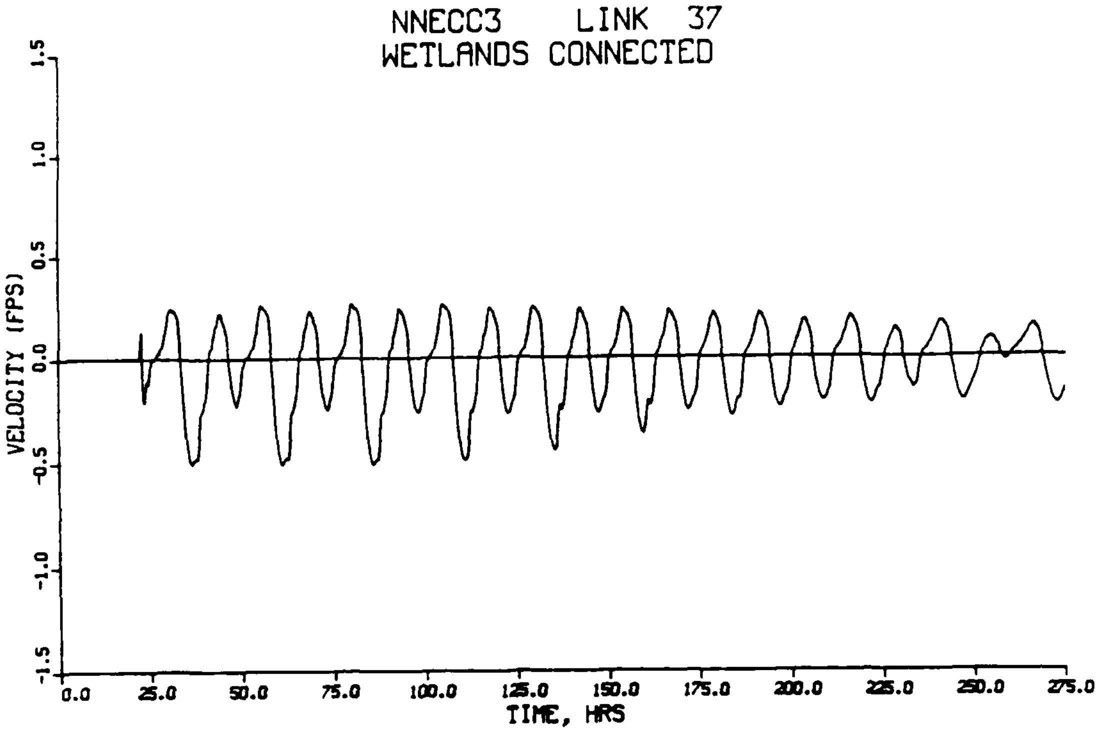


Figure H25. Average channel velocities in Outer Bolsa Bay under non-navigable entrance, by-pass connector channel to marina conditions

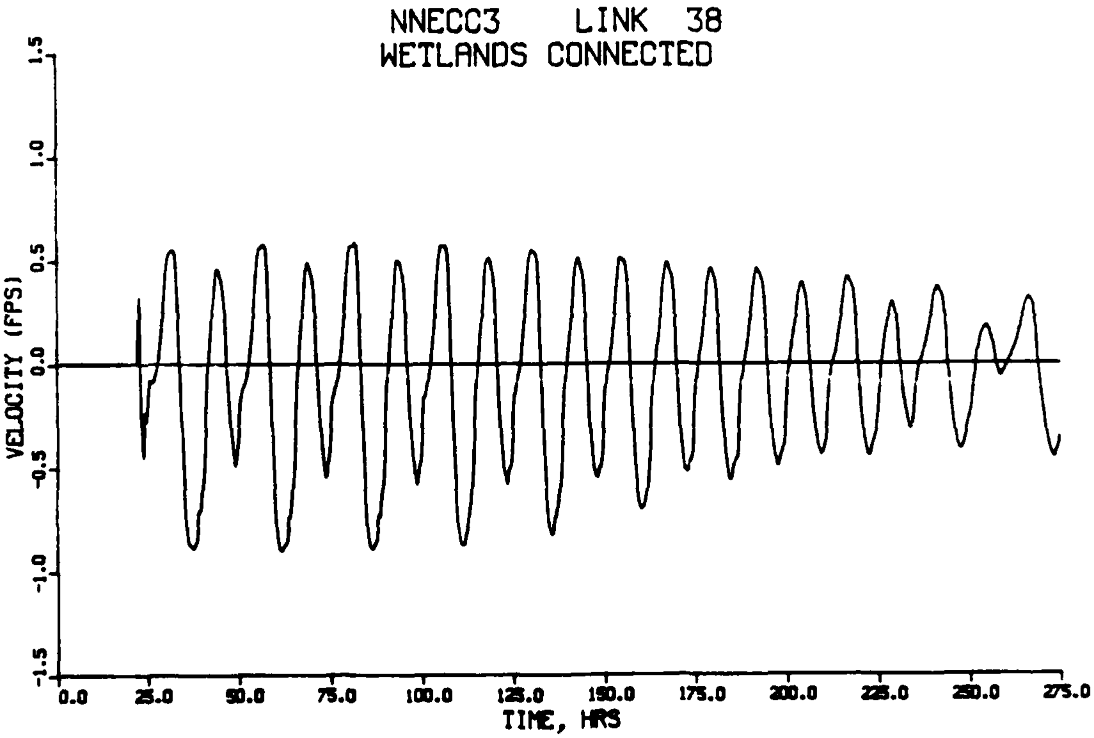


Figure H26. Average channel velocities in Outer Bolsa Bay under non-navigable entrance, by-pass connector channel to marina conditions

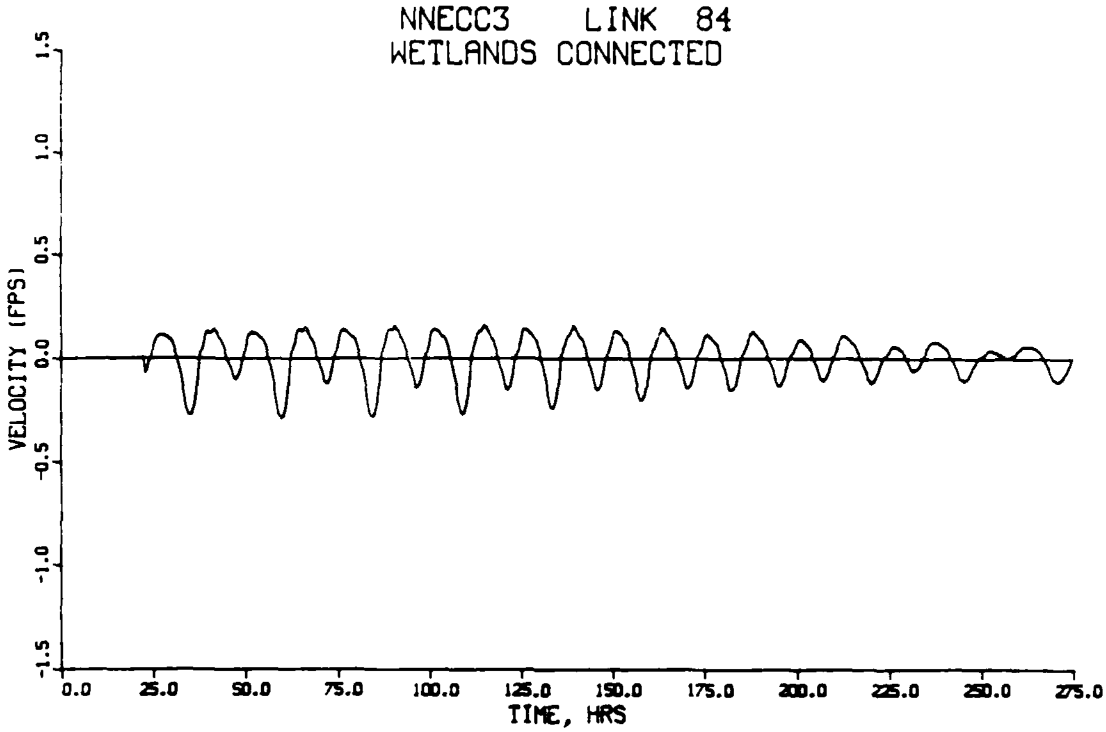


Figure H27. Average channel velocities in channel to proposed marina under non-navigable entrance, by-pass connector channel to marina conditions

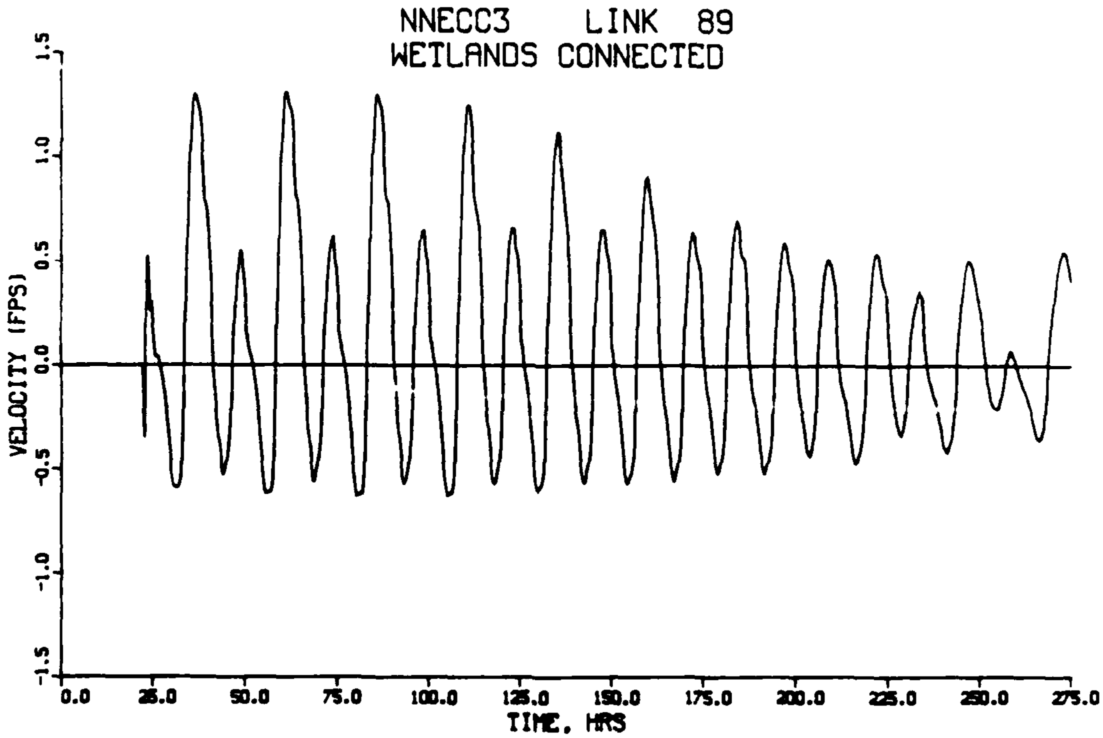


Figure H28. Average channel velocities in by-pass connector channel under non-navigable entrance, by-pass connector channel to marina conditions

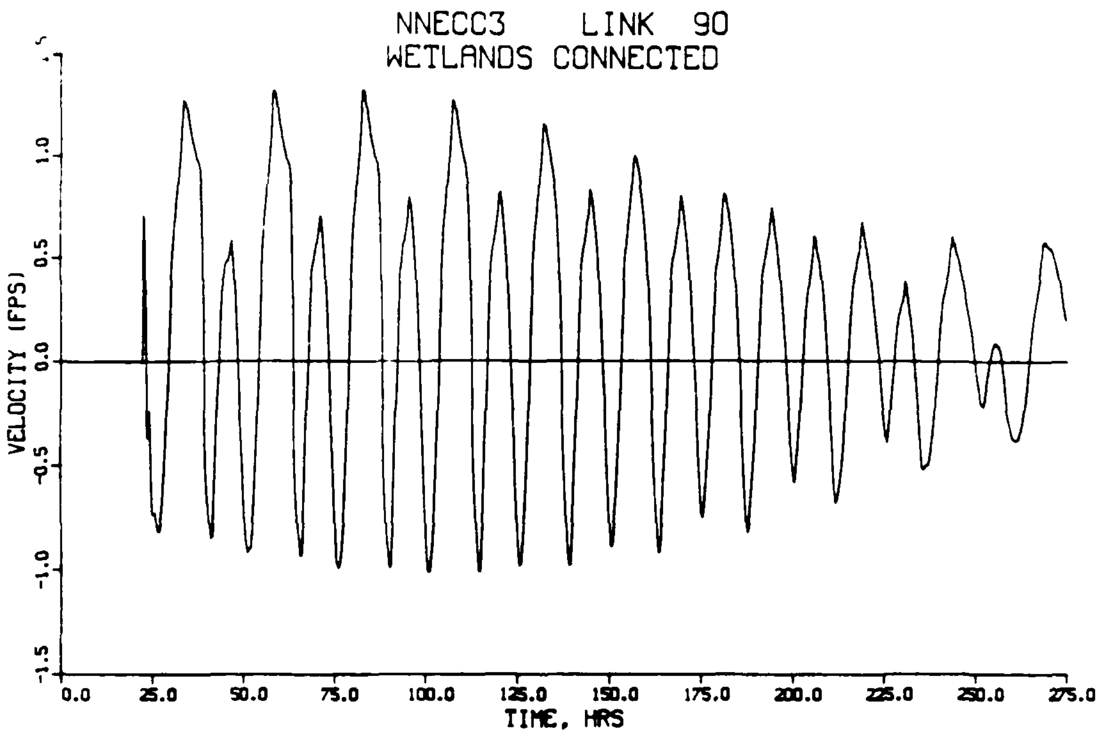


Figure H29. Average channel velocities in entrance channel under non-navigable entrance, by-pass connector channel to marina conditions

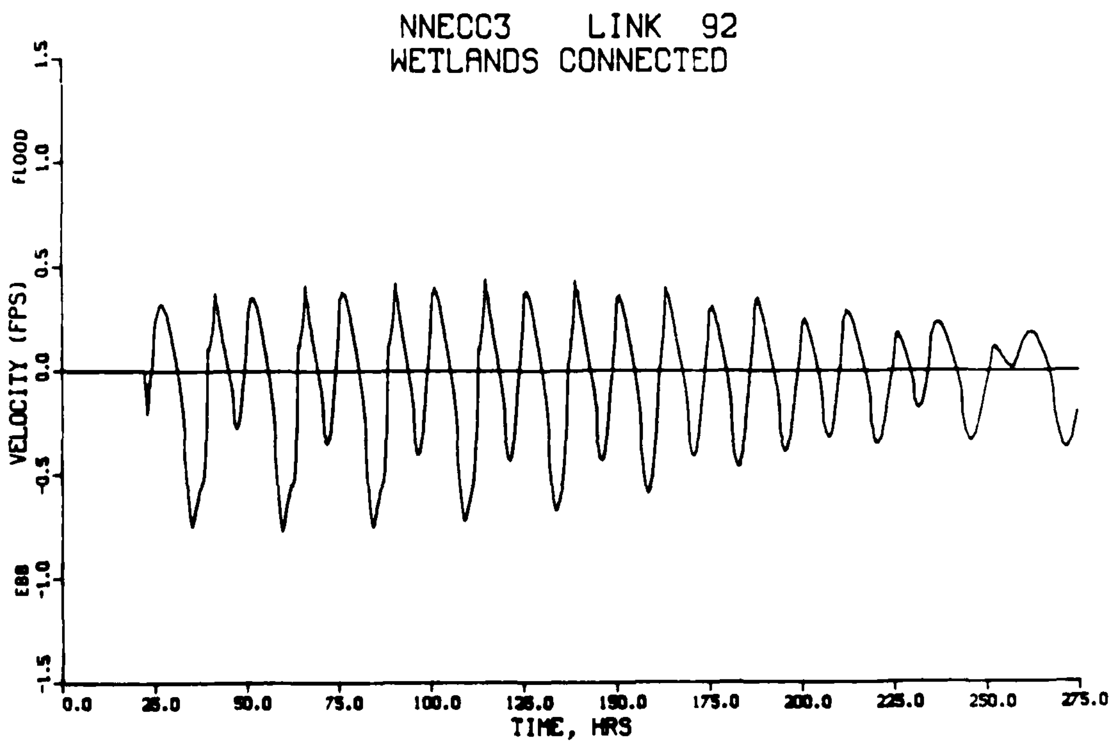


Figure H30. Average channel velocities in EGG-WFCC under non-navigable entrance, by-pass connector channel to marina conditions

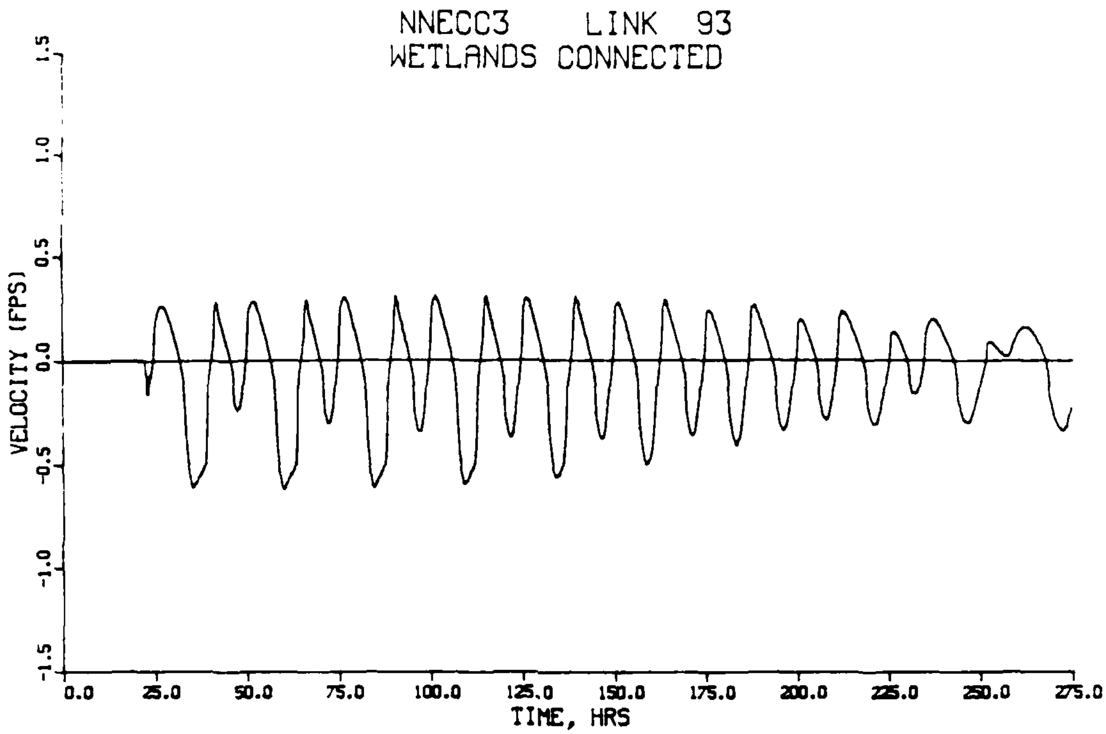


Figure H31. Average channel velocities in EGG-WFCC under non-navigable entrance, by-pass connector channel to marina conditions

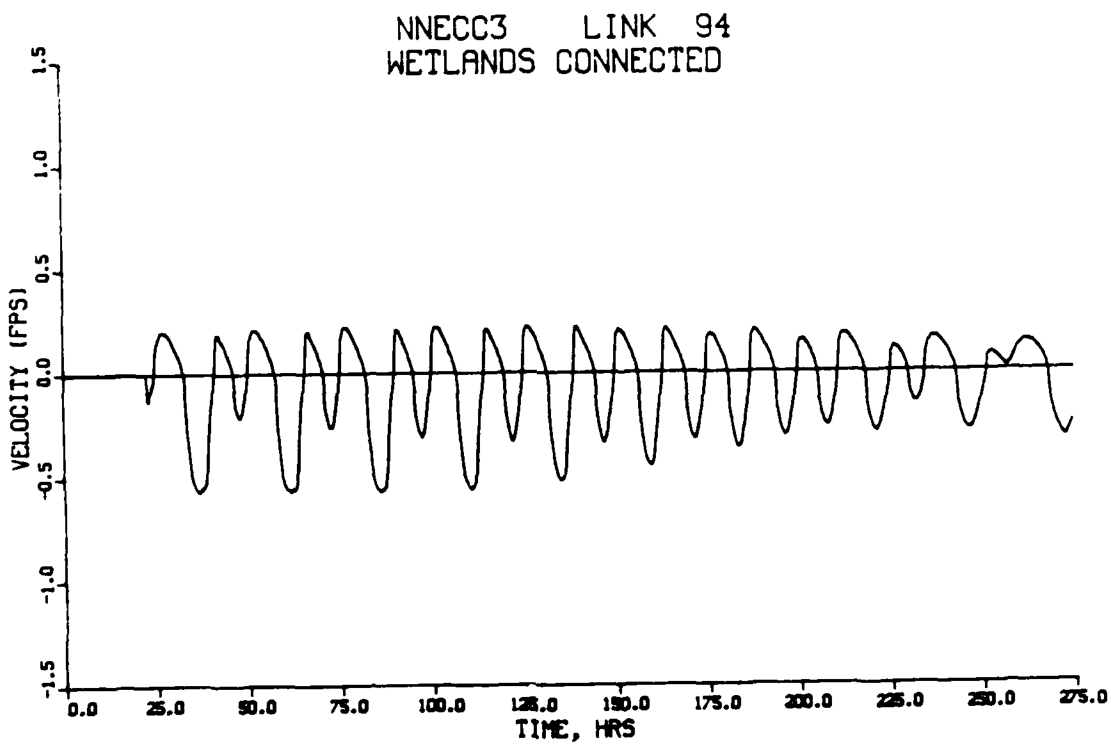


Figure H32. Average channel velocities in EGG-WFCC under non-navigable entrance, by-pass connector channel to marina conditions

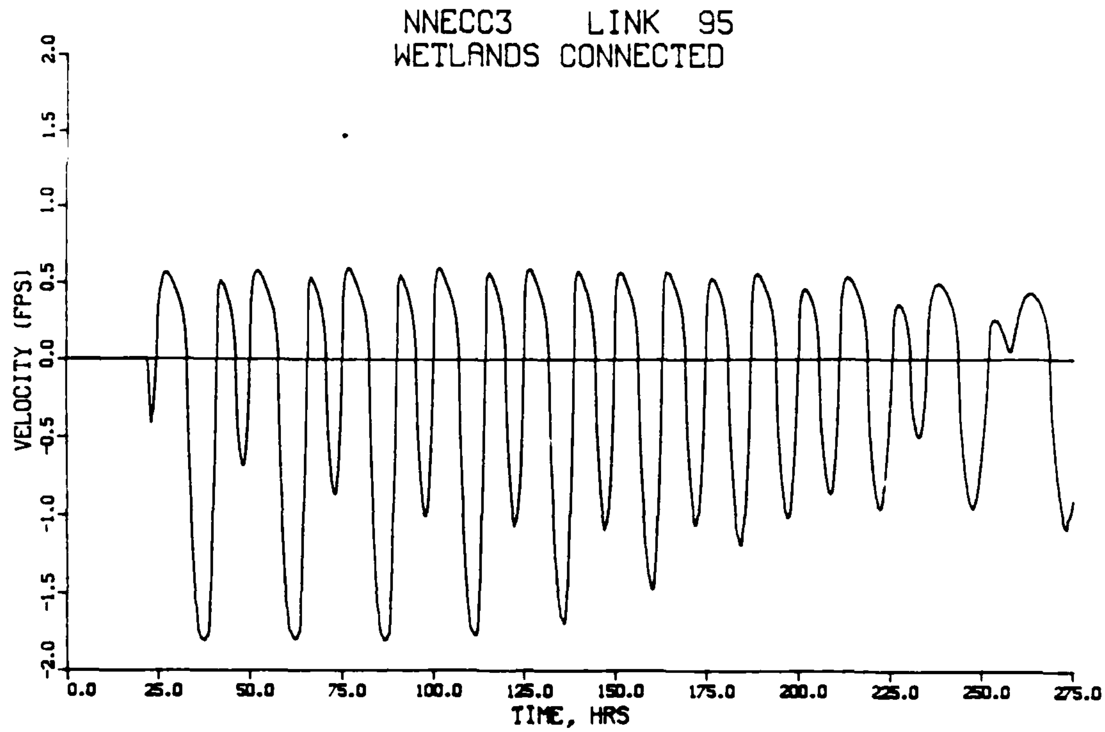


Figure H33. Average channel velocities in channel to muted wetlands under non-navigable entrance, by-pass connector channel to marina conditions

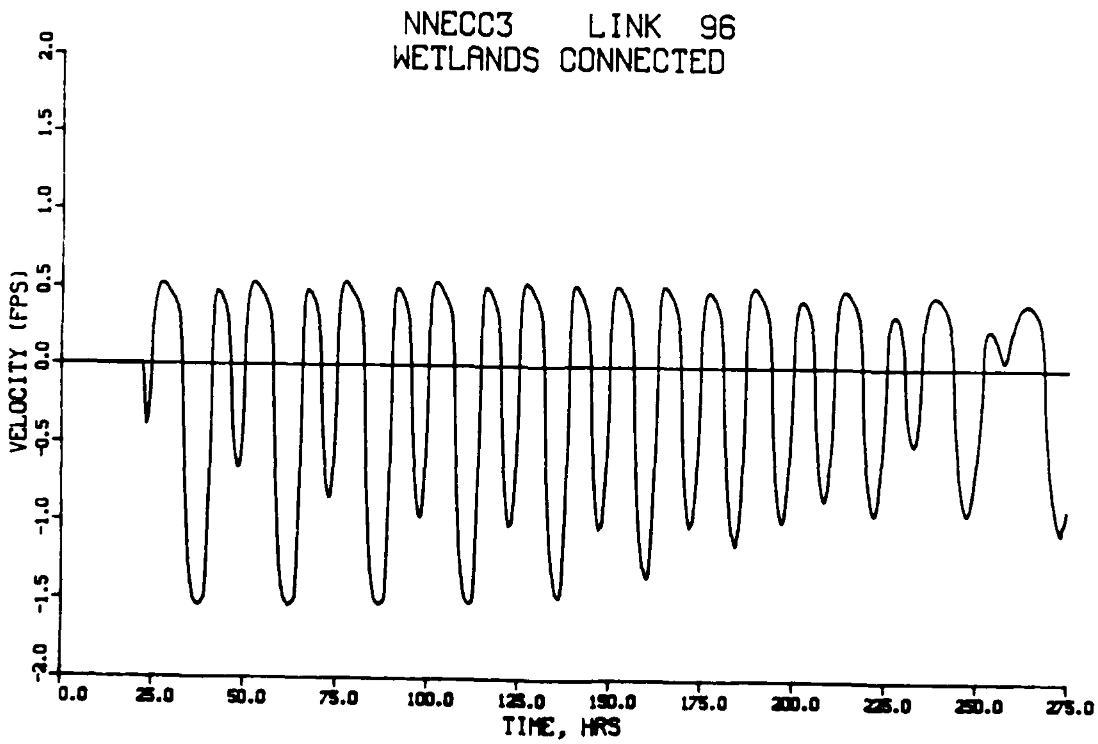


Figure H34. Average channel velocities in channel to muted wetlands under non-navigable entrance, by-pass connector channel to marina conditions

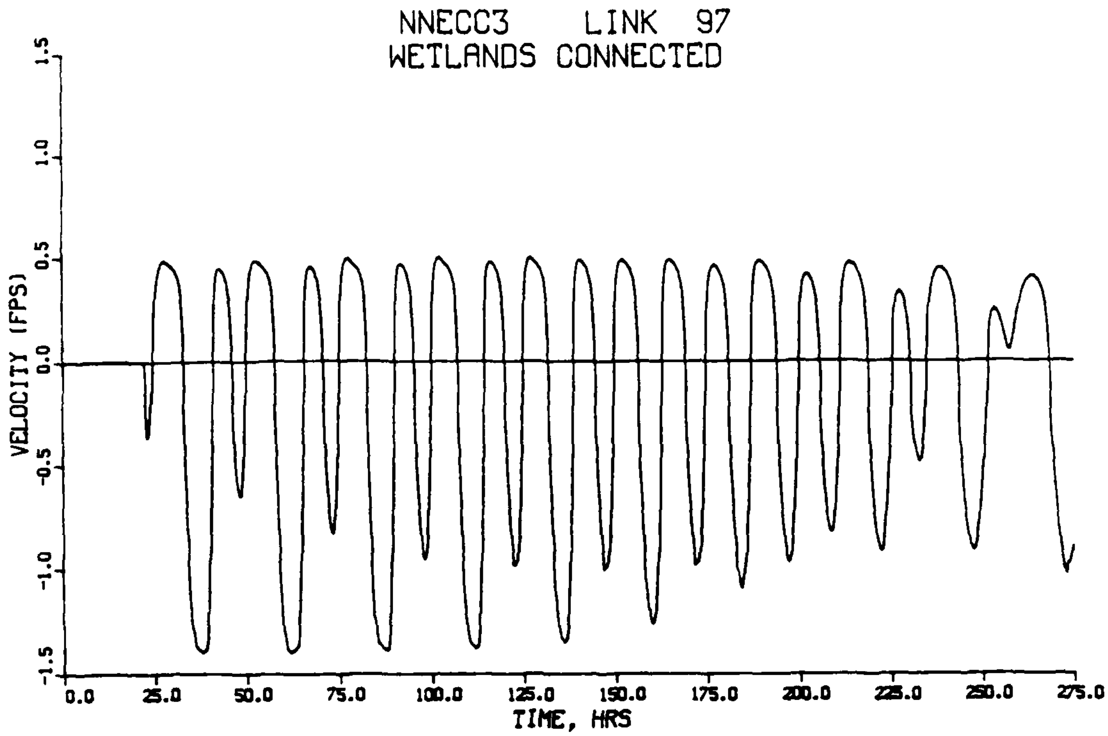


Figure H35. Average channel velocities in channel to muted wetlands under non-navigable entrance, by-pass connector channel to marina conditions

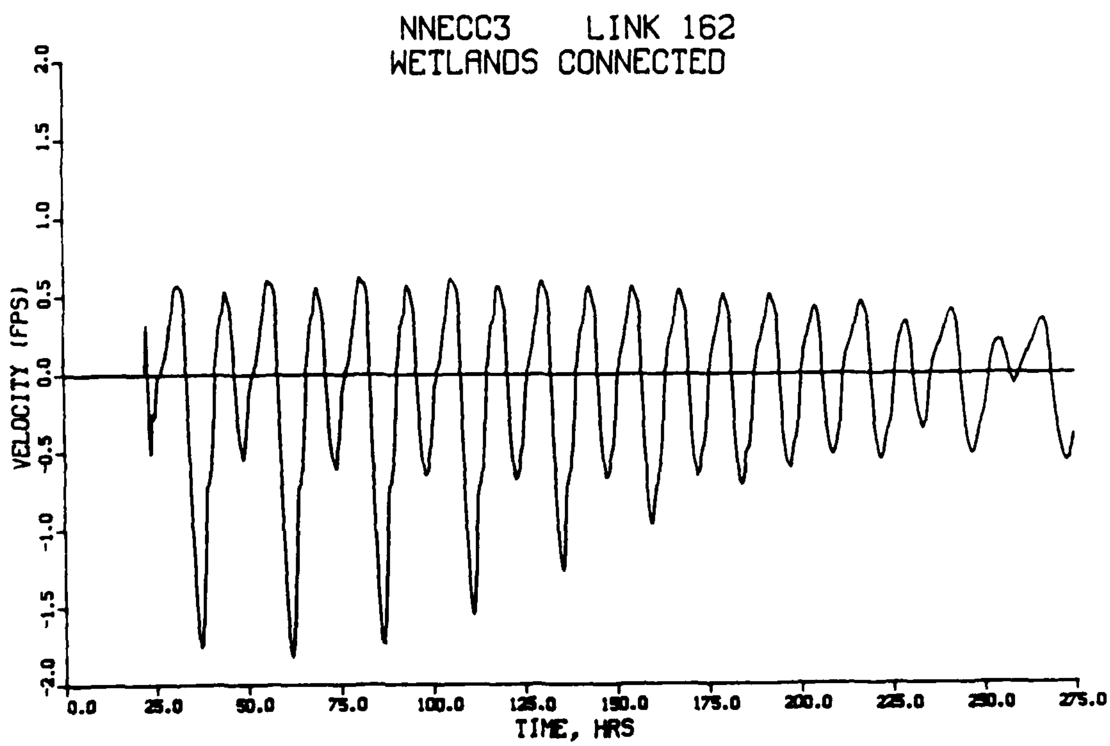


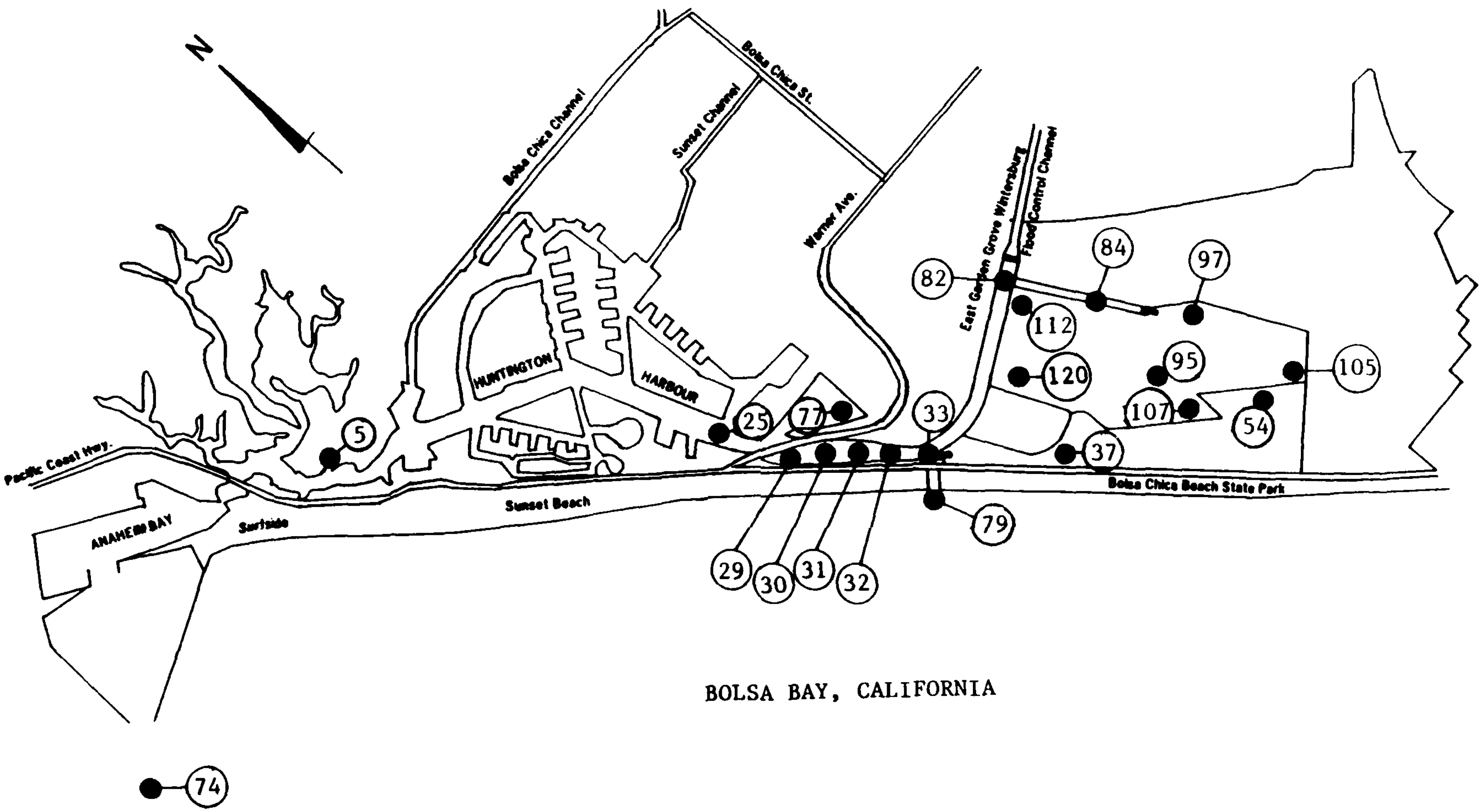
Figure H36. Average channel velocities in by-pass connector channel under non-navigable entrance, by-pass connector channel to marina conditions

APPENDIX I:

NNECC4

NON-NAVIGABLE ENTRANCE CHANNEL
AND
NO BY-PASS CONNECTOR CHANNEL TO MARINA

WATER SURFACE ELEVATIONS



BOLSA BAY, CALIFORNIA

NNECC4
Location of nodes for displaying water surface elevations
under non-navigable entrance channel and no by-pass connector channel to marina conditions

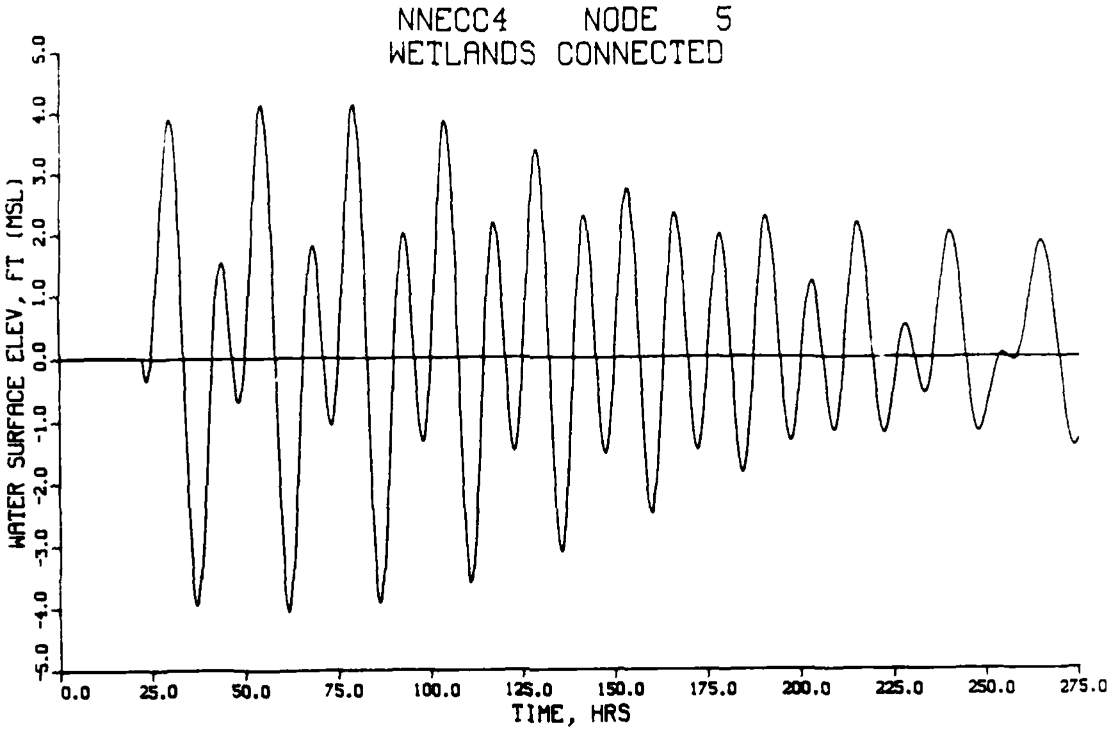


Figure I1. Tidal elevations in Huntington Harbour under non-navigable entrance, no by-pass connector channel to marina conditions

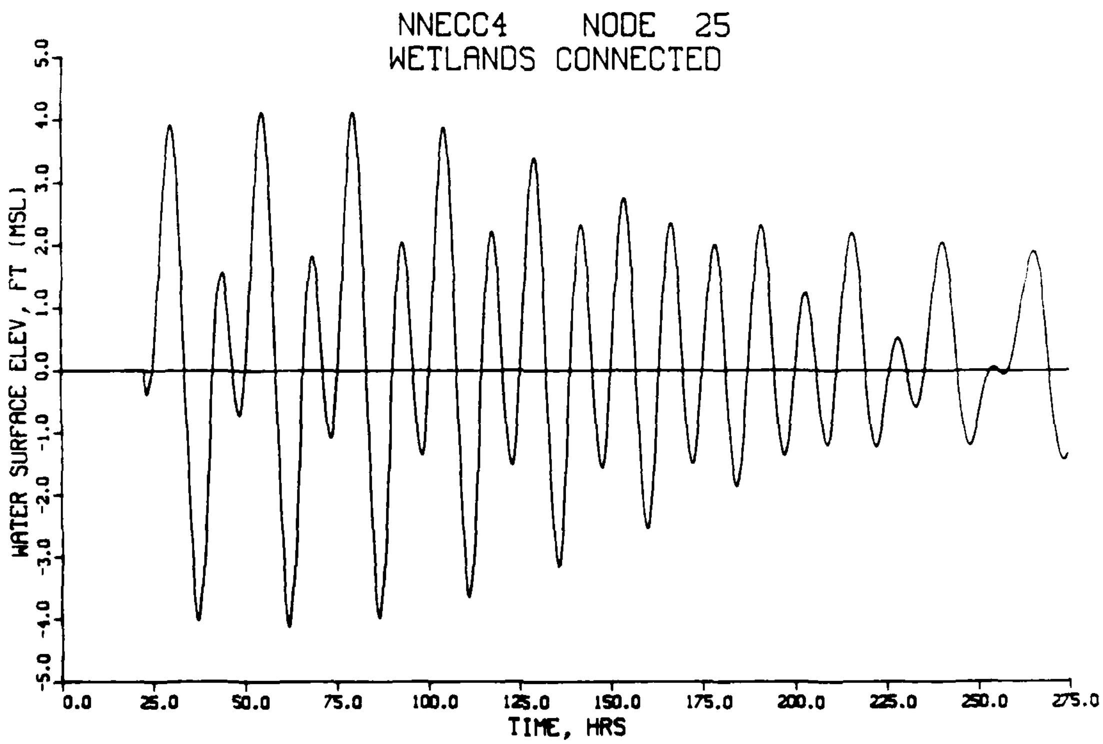


Figure I2. Tidal elevations in Huntington Harbour under non-navigable entrance, no by-pass connector channel to marina conditions

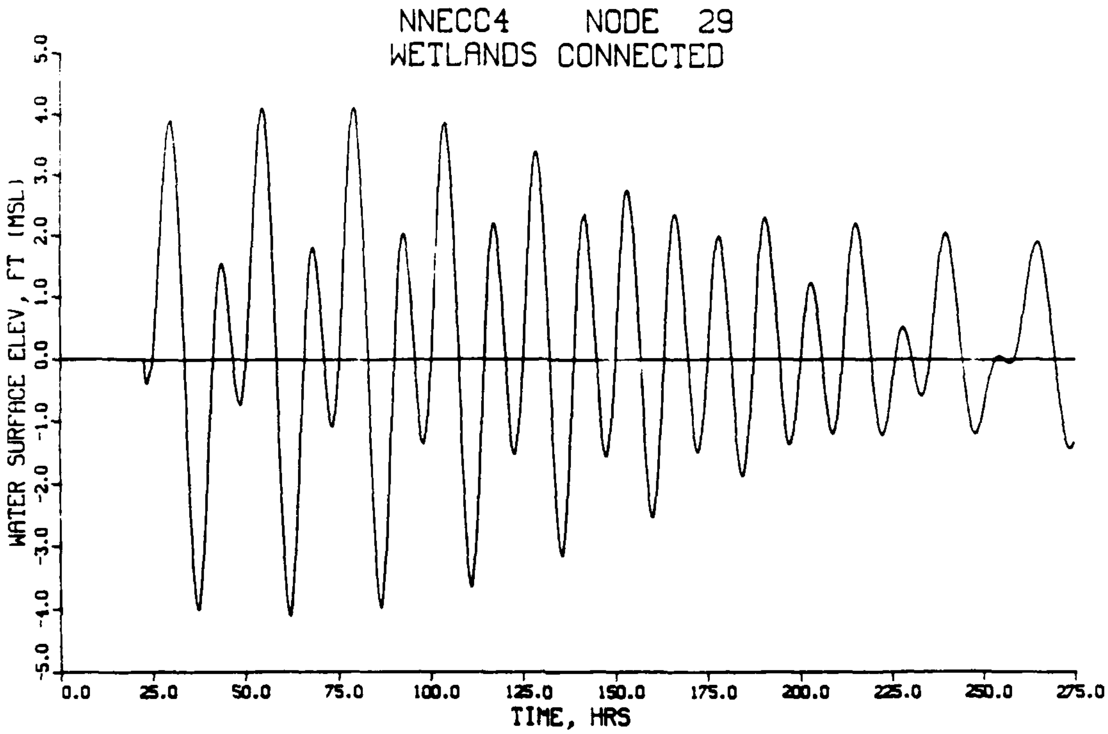


Figure I3. Tidal elevations in Outer Bolsa Bay under non-navigable entrance, no by-pass connector channel to marina conditions

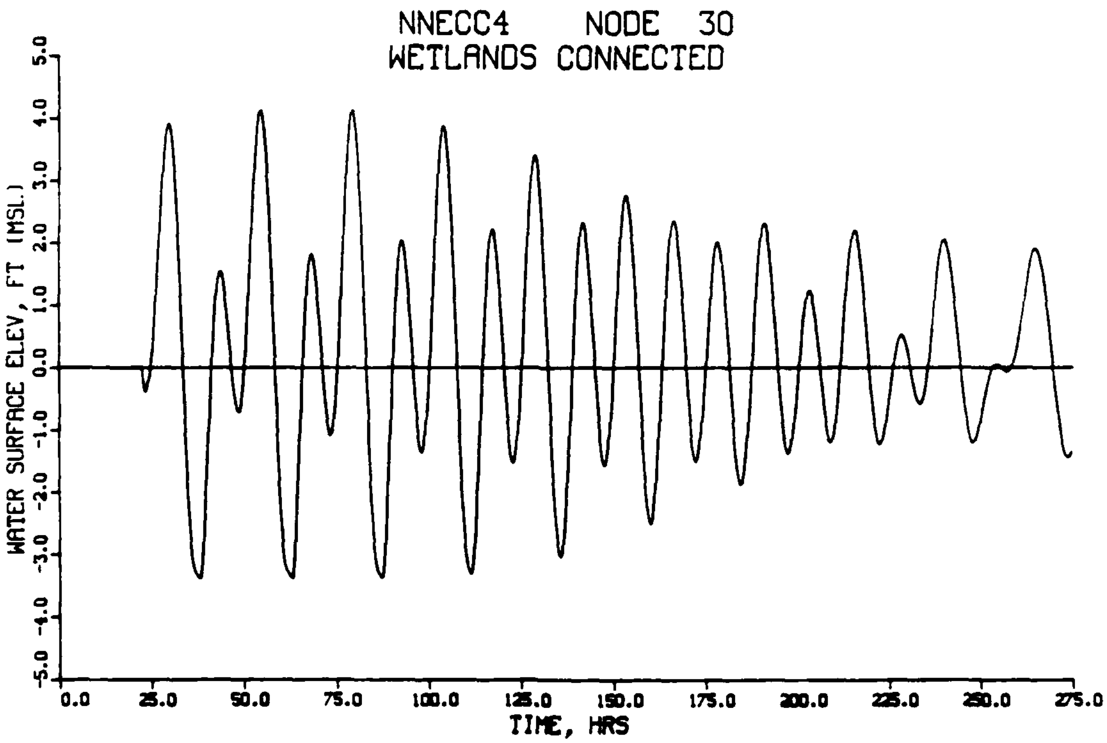


Figure I4. Tidal elevations in Outer Bolsa Bay under non-navigable entrance, no by-pass connector channel to marina conditions

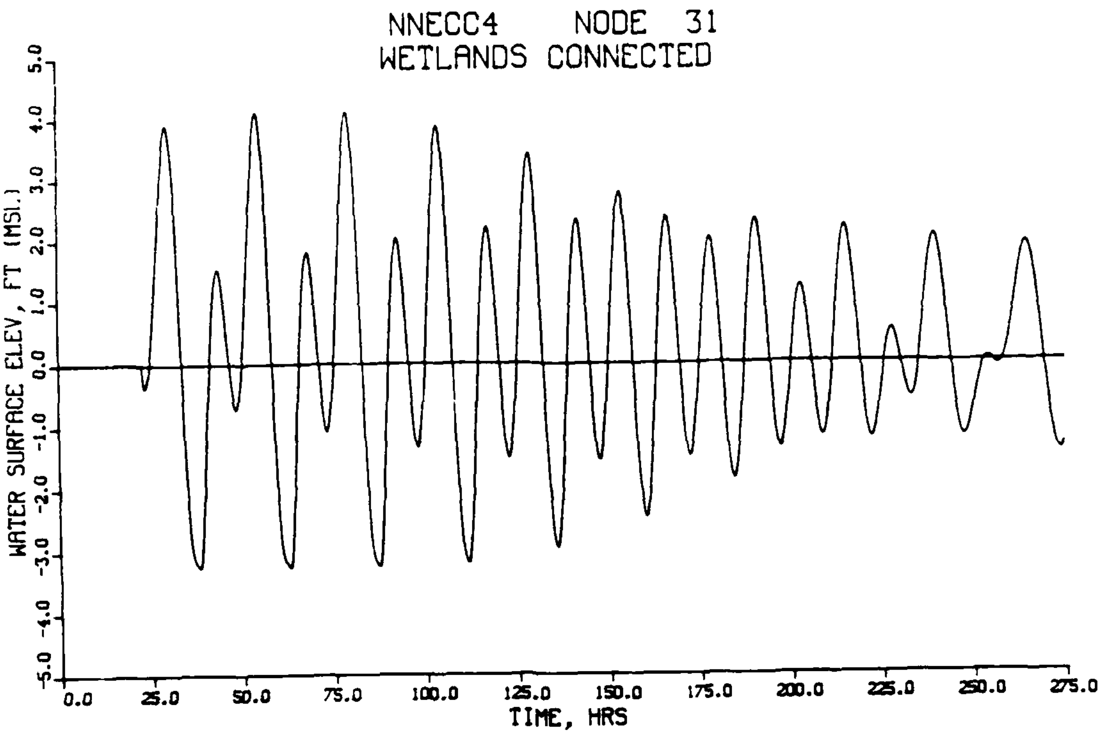


Figure I5. Tidal elevations in Outer Bolsa Bay under non-navigable entrance, no by-pass connector channel to marina conditions

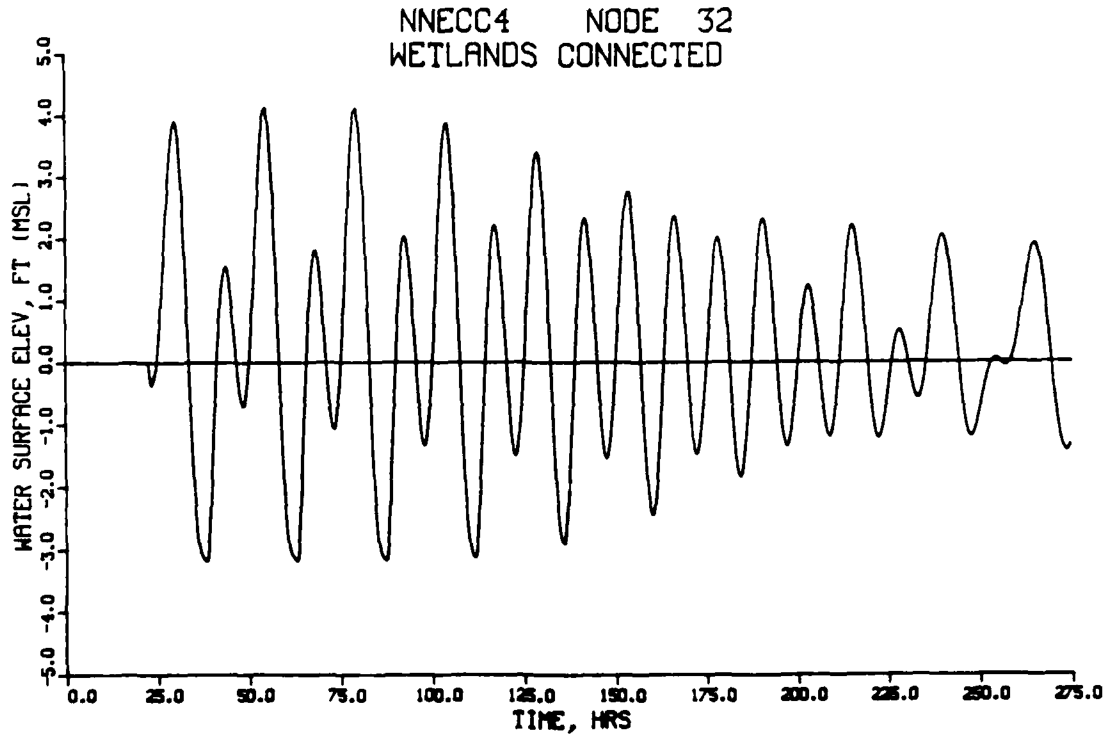


Figure I6. Tidal elevations in Outer Bolsa Bay under non-navigable entrance, no by-pass connector channel to marina conditions

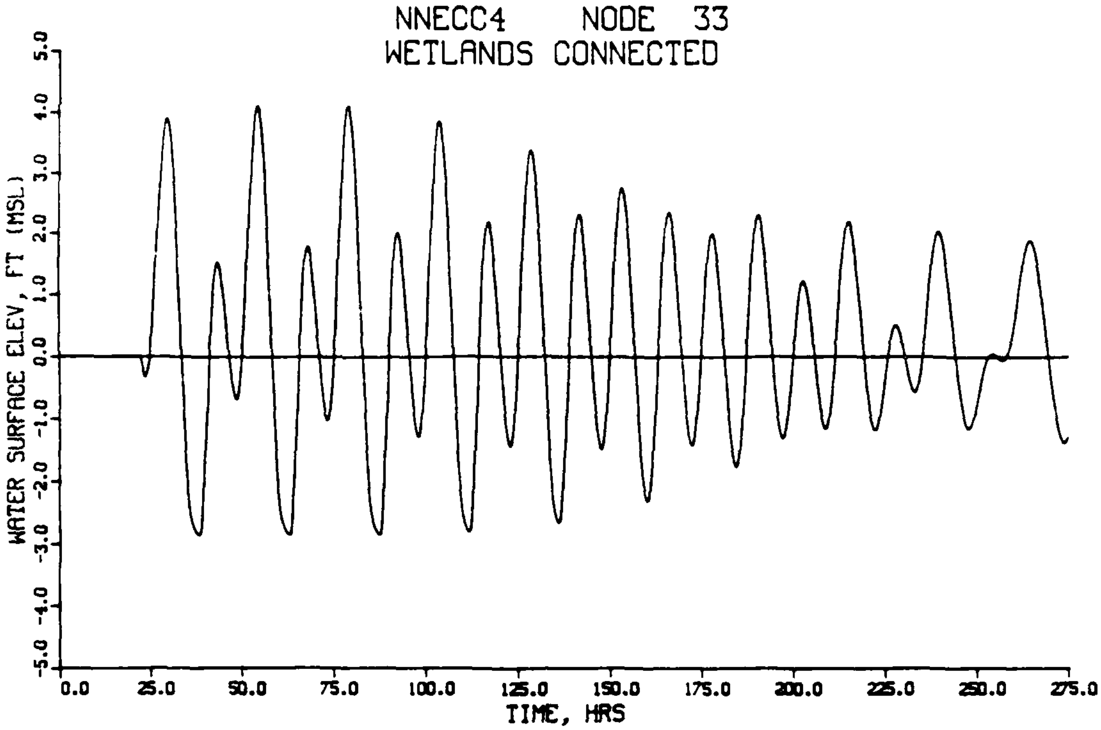


Figure I7. Tidal elevations in entrance channel under non-navigable entrance, no by-pass connector channel to marina conditions

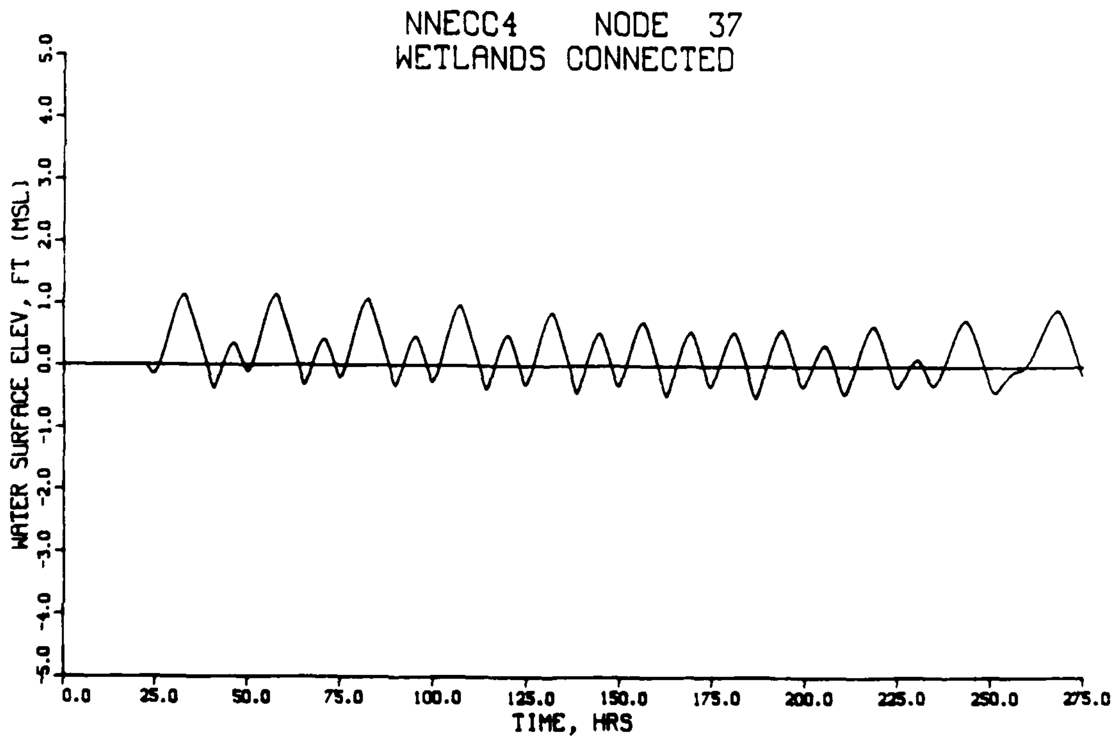


Figure I8. Tidal elevations in Inner Bolsa Bay under non-navigable entrance, no by-pass connector channel to marina conditions

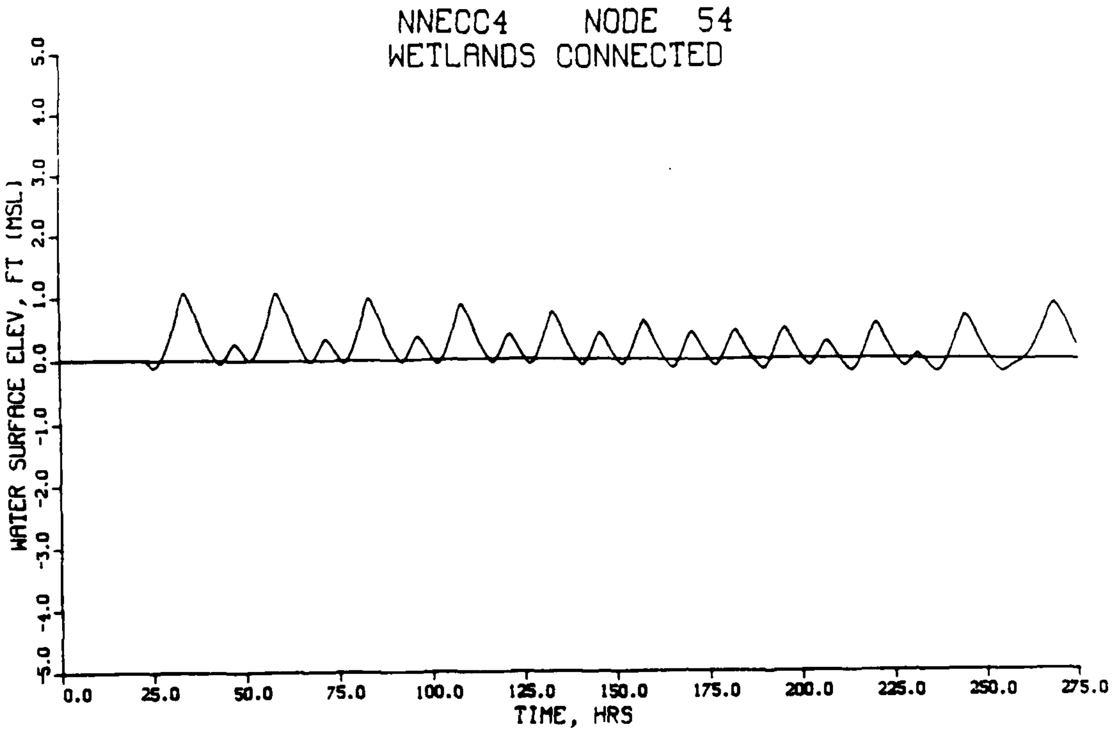


Figure I9. Tidal elevations in DFG muted tidal cell under non-navigable entrance, no by-pass connector channel to marina conditions

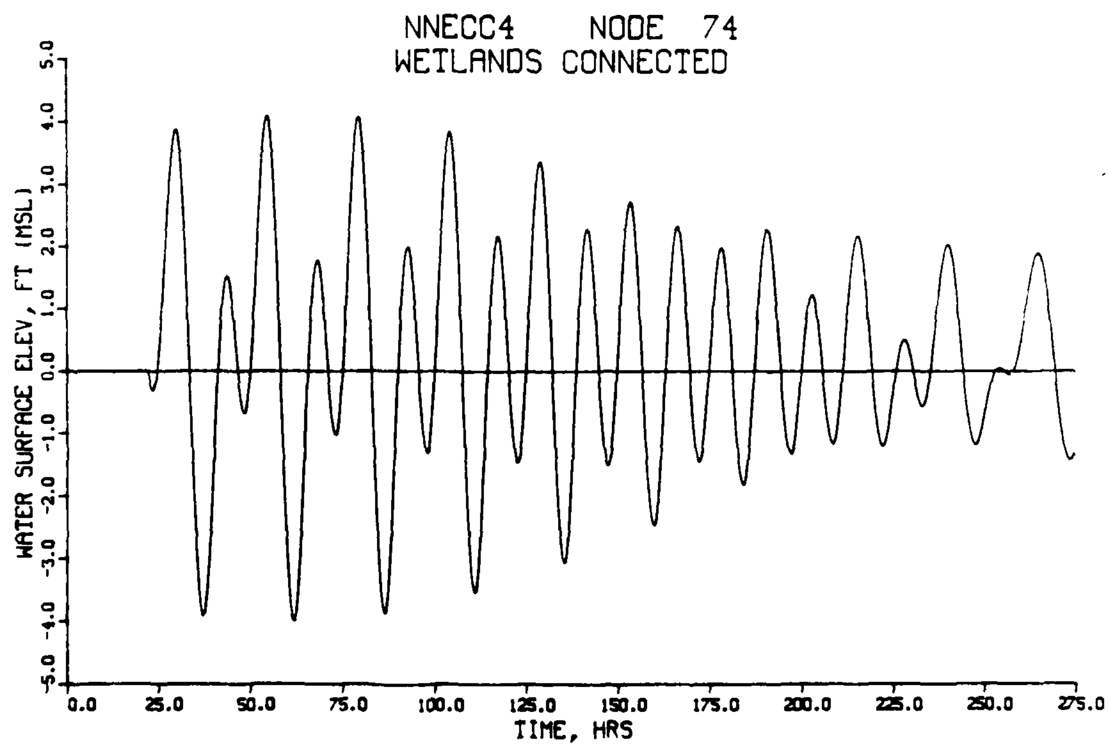


Figure I10. Tidal elevations in Pacific Ocean, driving non-navigable entrance, no by-pass connector channel to marina conditions

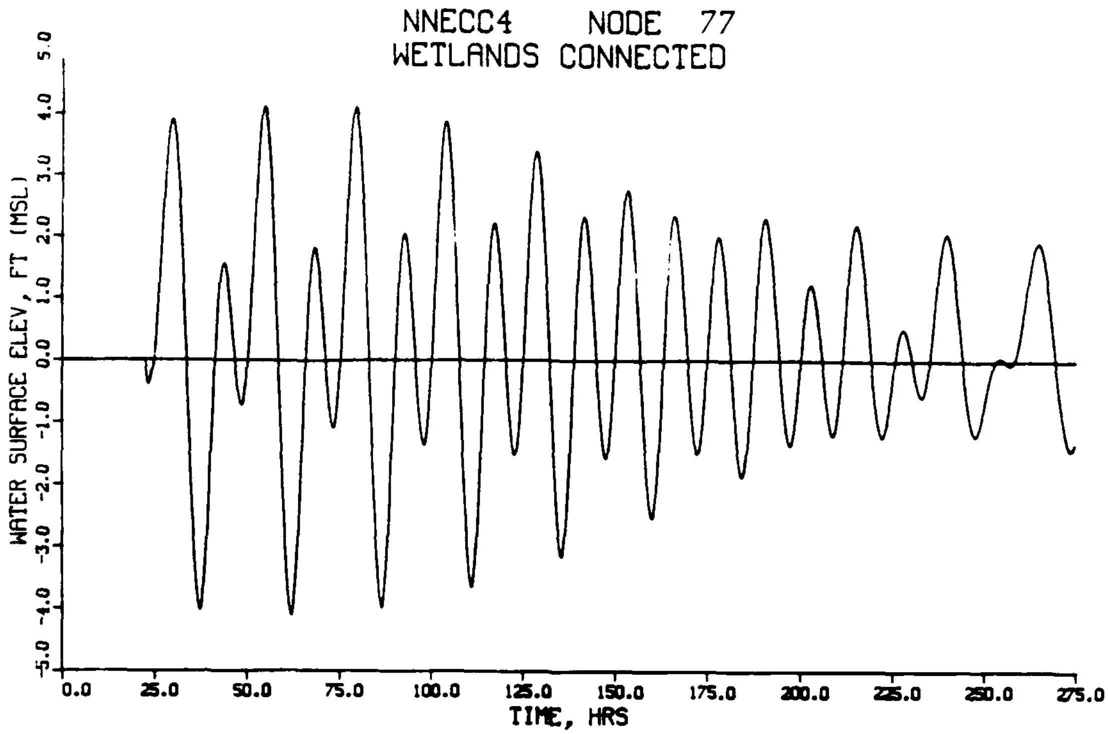


Figure I11. Tidal elevations in proposed marina under non-navigable entrance, no by-pass connector channel to marina conditions

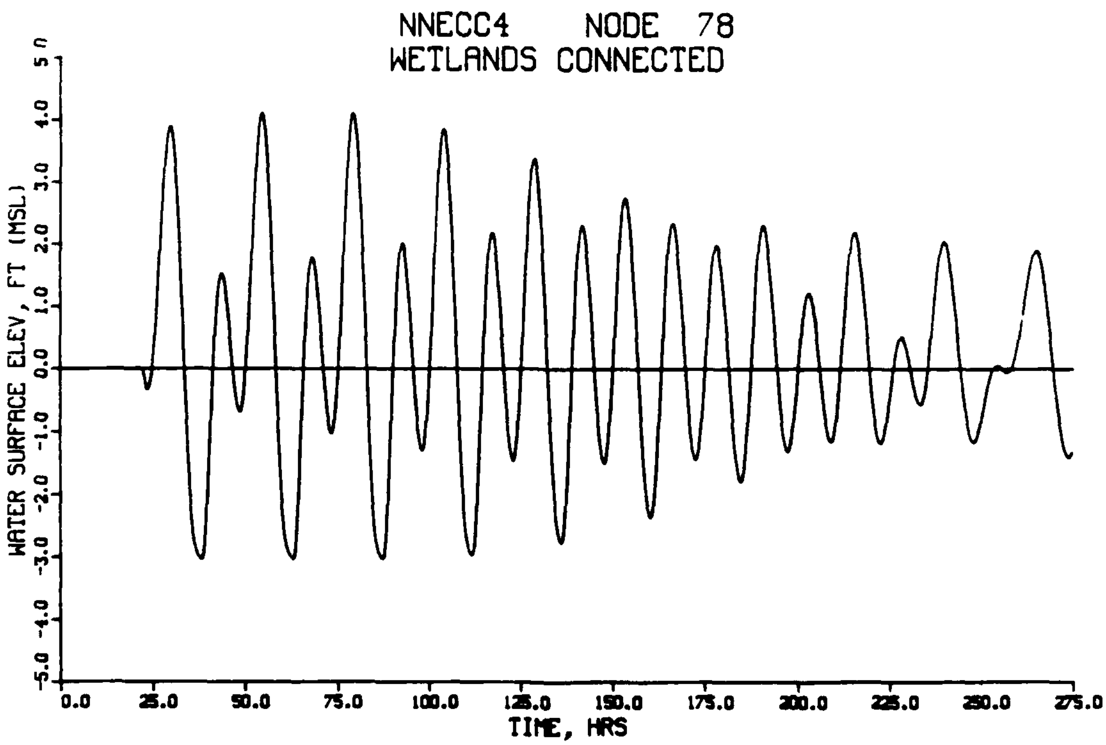


Figure I12. Tidal elevations in entrance channel under non-navigable entrance, no by-pass connector channel to marina conditions

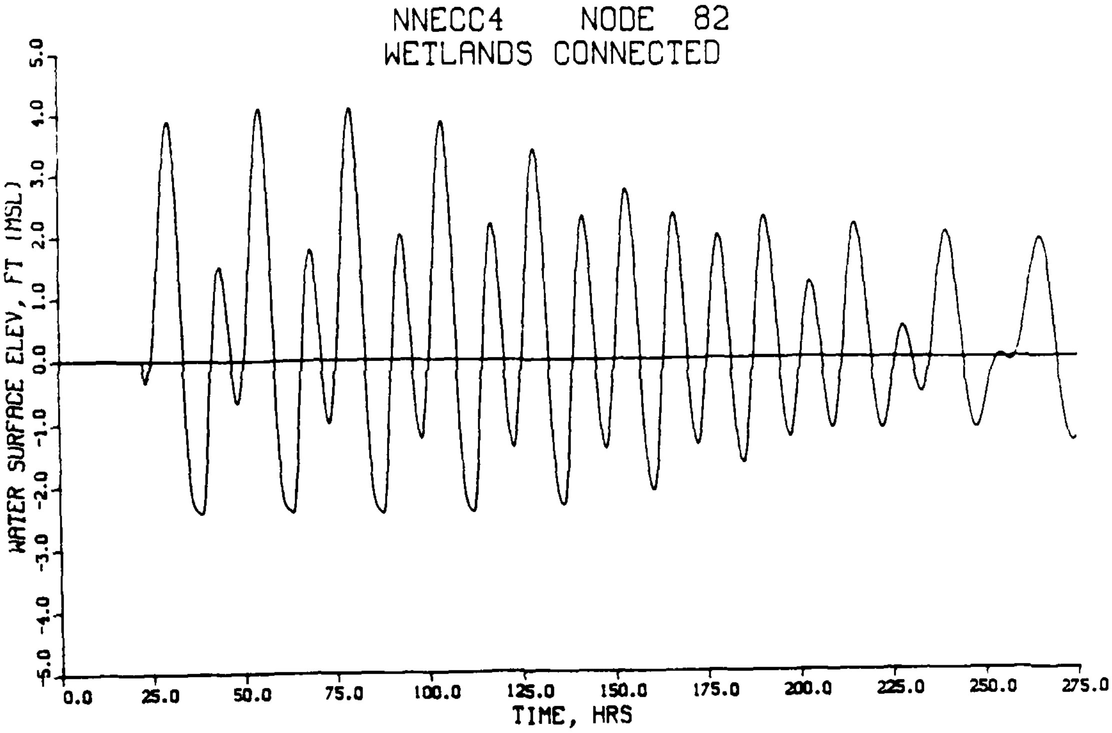


Figure I13. Tidal elevations in EGG-WFCC under non-navigable entrance, no by-pass connector channel to marina conditions

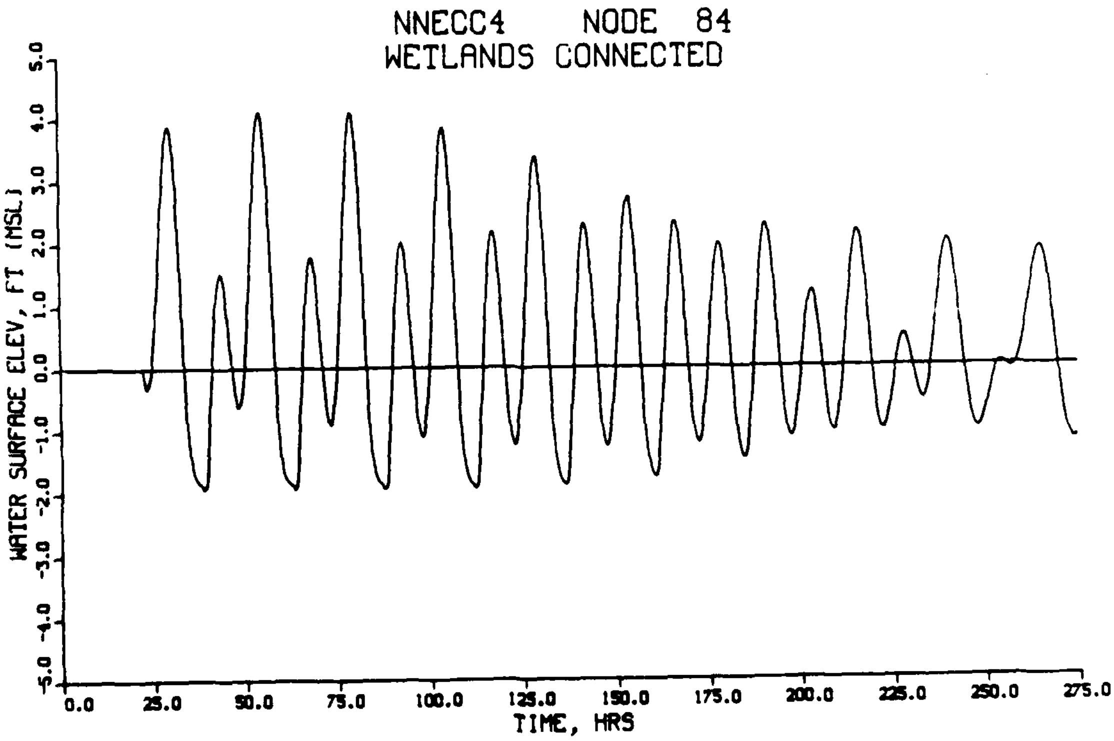


Figure I14. Tidal elevations in channel to proposed muted wetlands under non-navigable entrance, no by-pass connector channel to marina conditions

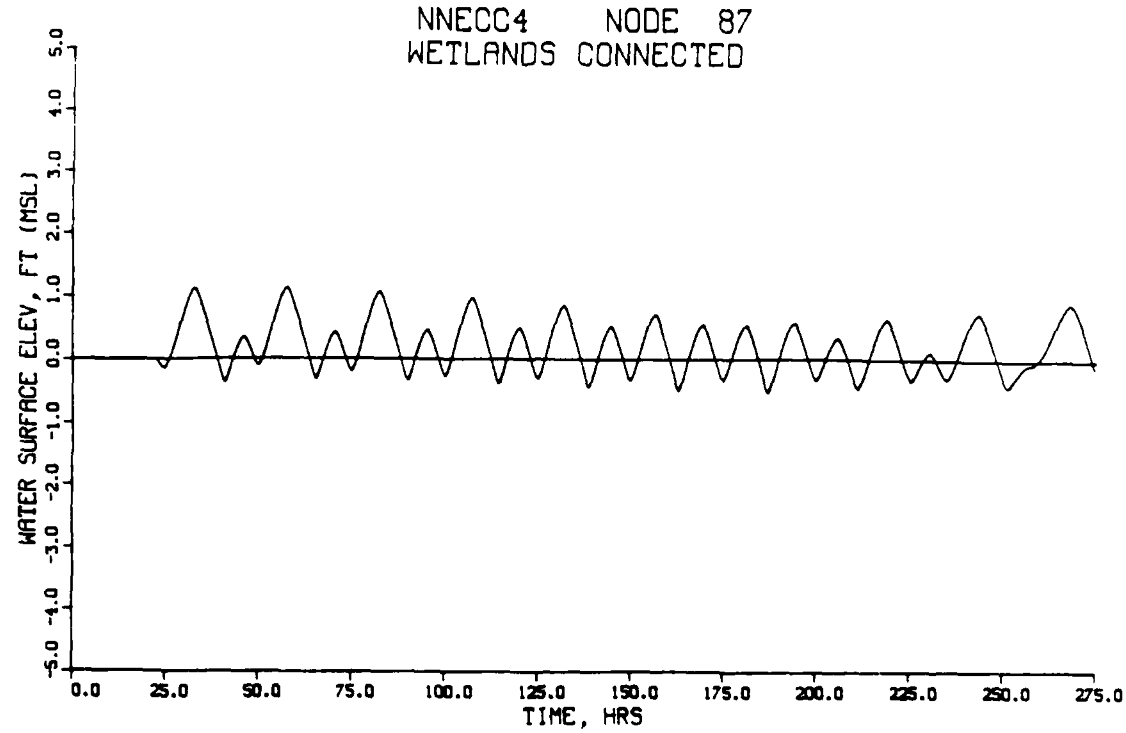


Figure I15. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance, no by-pass connector channel to marina conditions

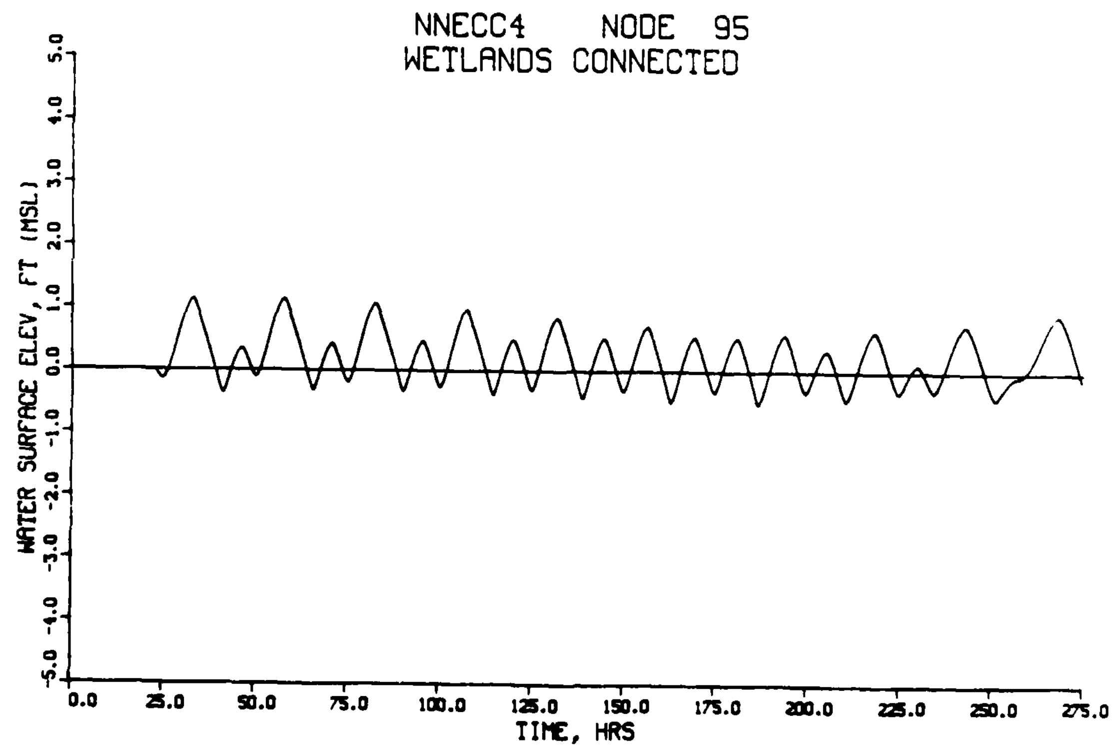


Figure I16. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance, no by-pass connector channel to marina conditions

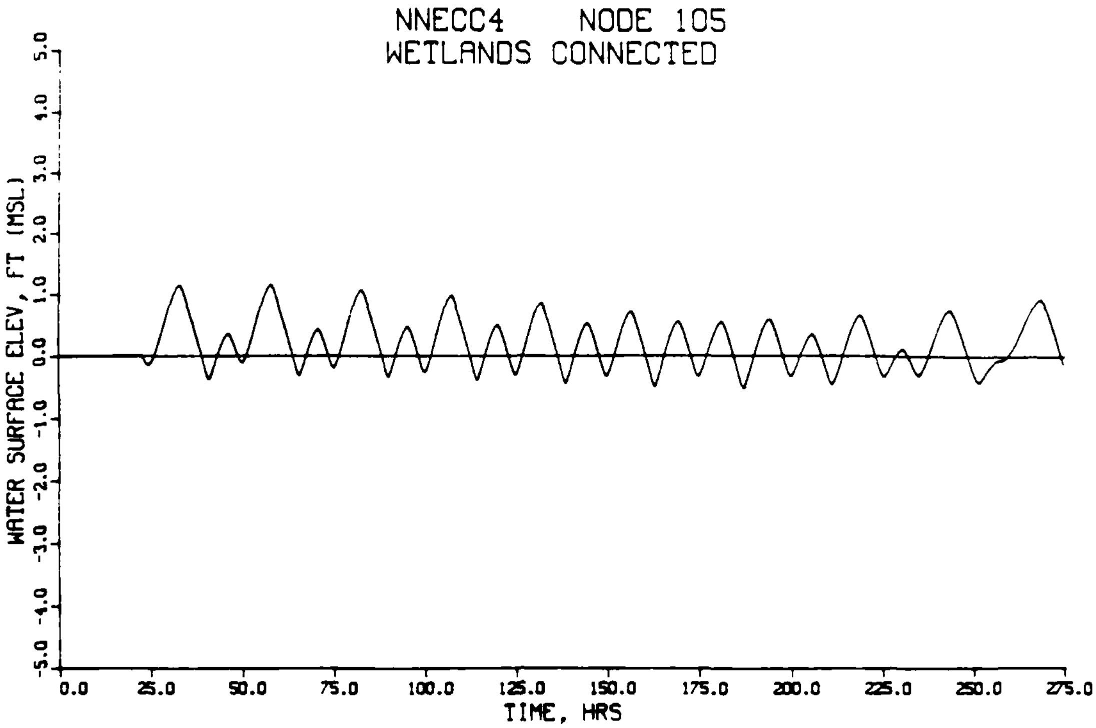


Figure I17. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance, no by-pass connector channel to marina conditions

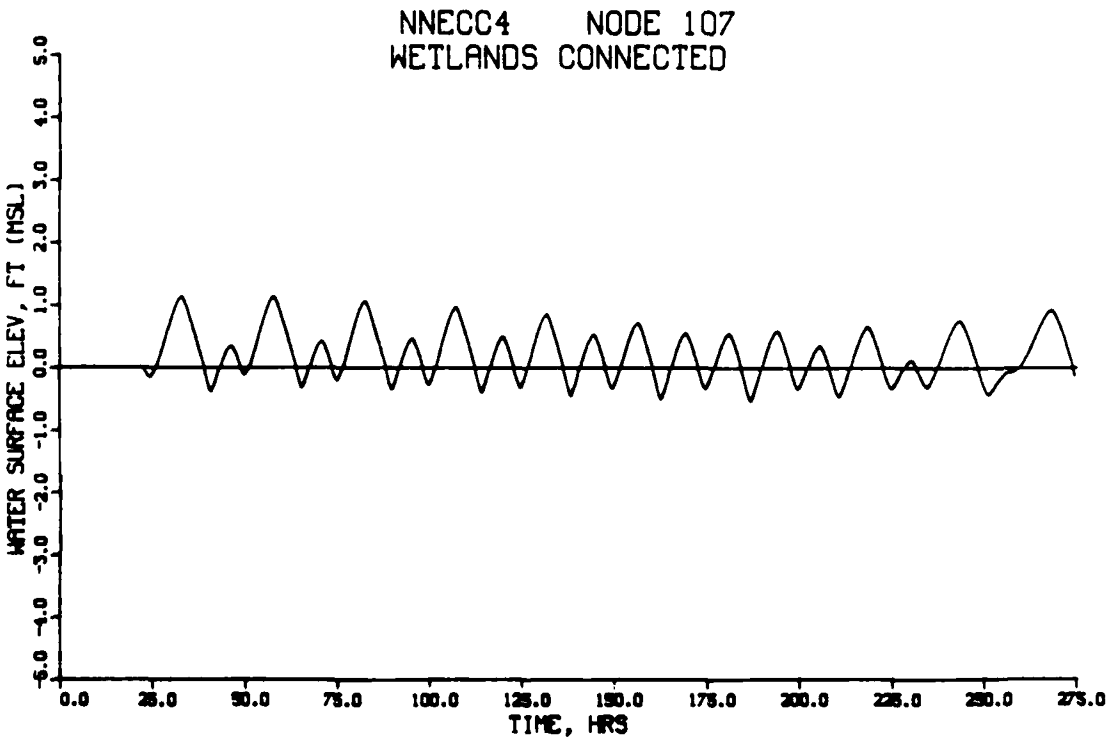


Figure I18. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance, no by-pass connector channel to marina conditions

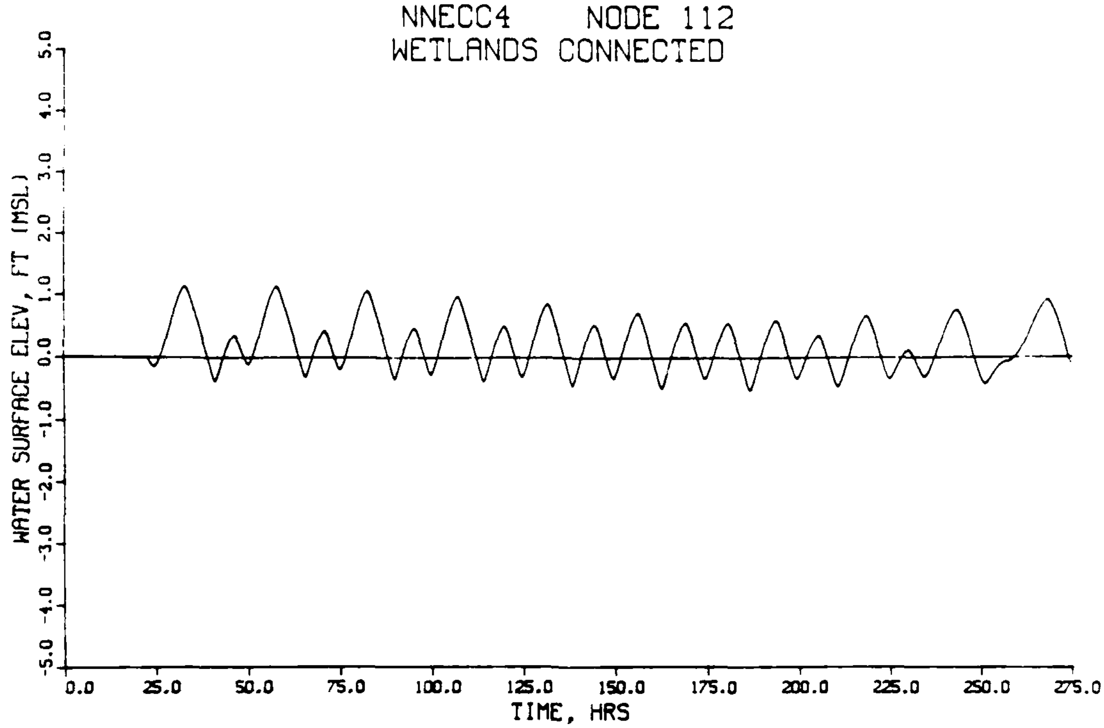


Figure I19. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance, no by-pass connector channel to marina conditions

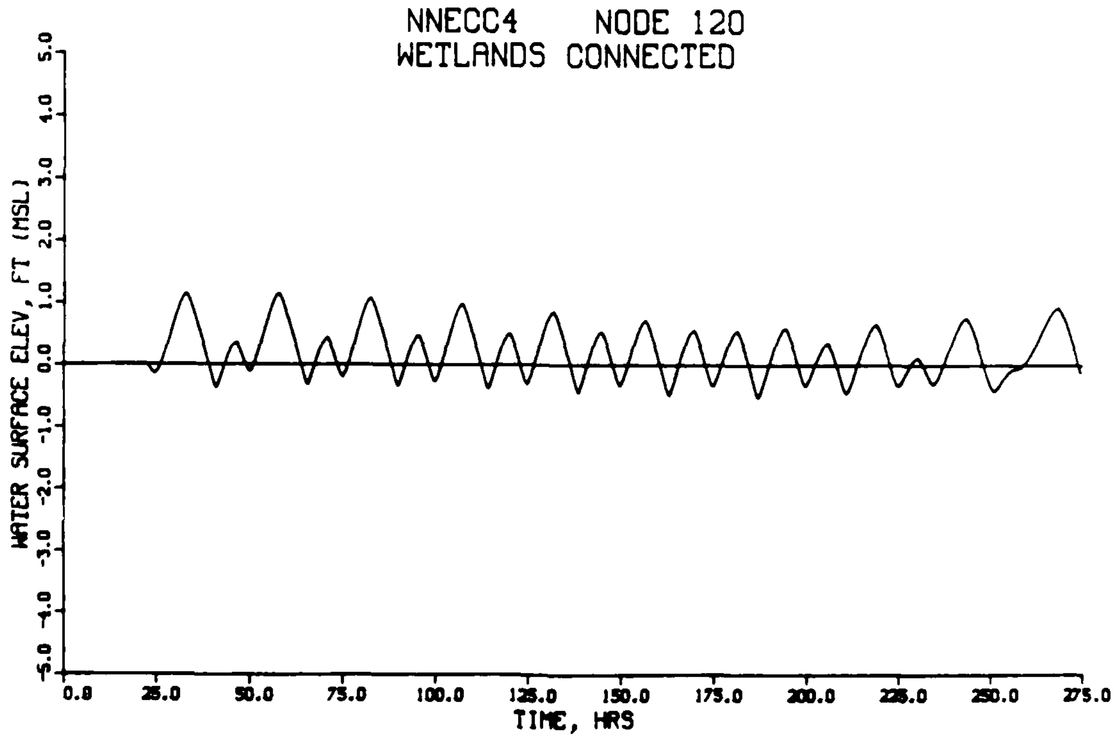


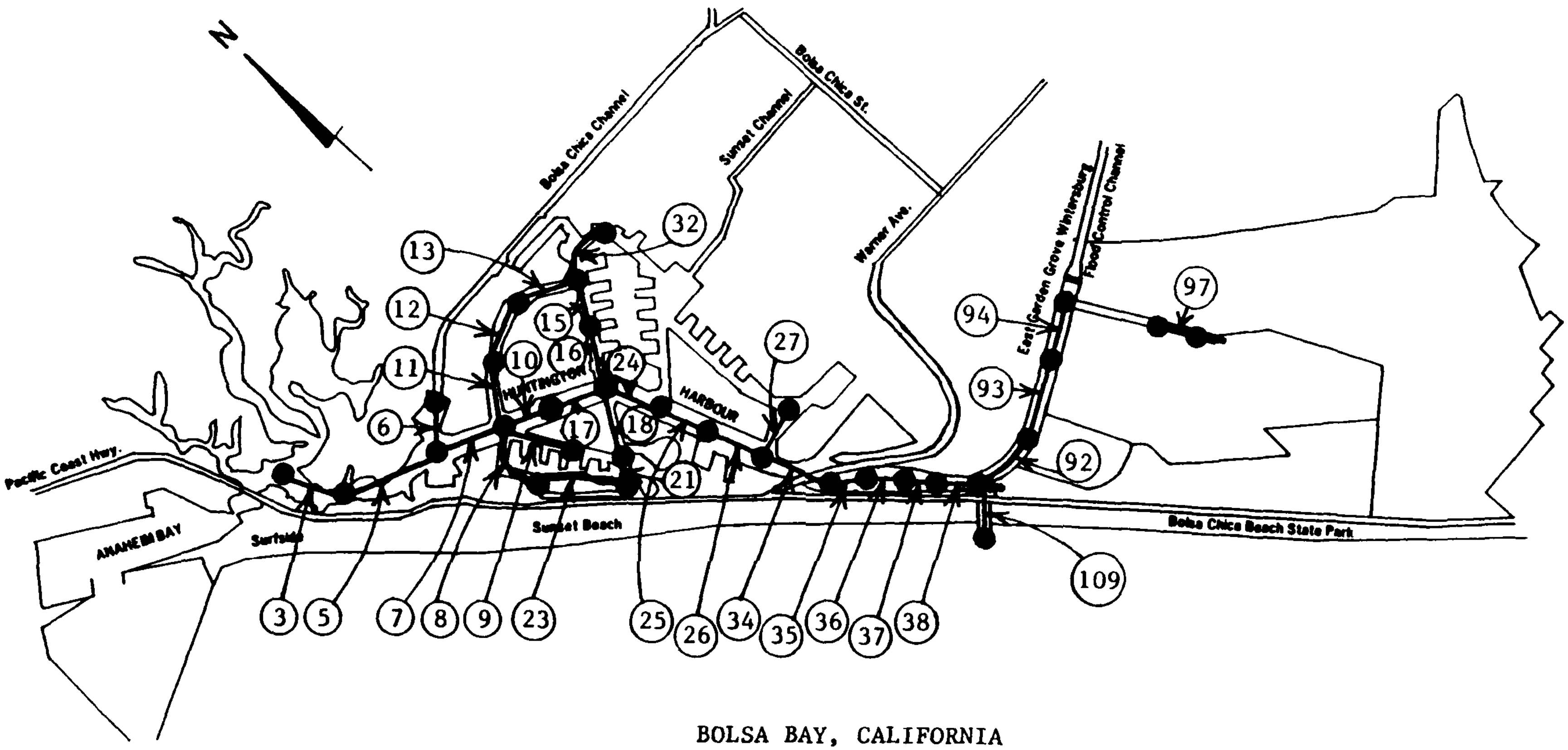
Figure I20. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance, no by-pass connector channel to marina conditions

APPENDIX J:

NNECC4

NON-NAVIGABLE ENTRANCE CHANNEL
AND
NO BY-PASS CONNECTOR CHANNEL TO MARINA

AVERAGE CHANNEL VELOCITIES



BOLSA BAY, CALIFORNIA

NNECC4
Location of links for displaying average channel velocities
under non-navigable entrance channel and no by-pass connector channel to marina conditions

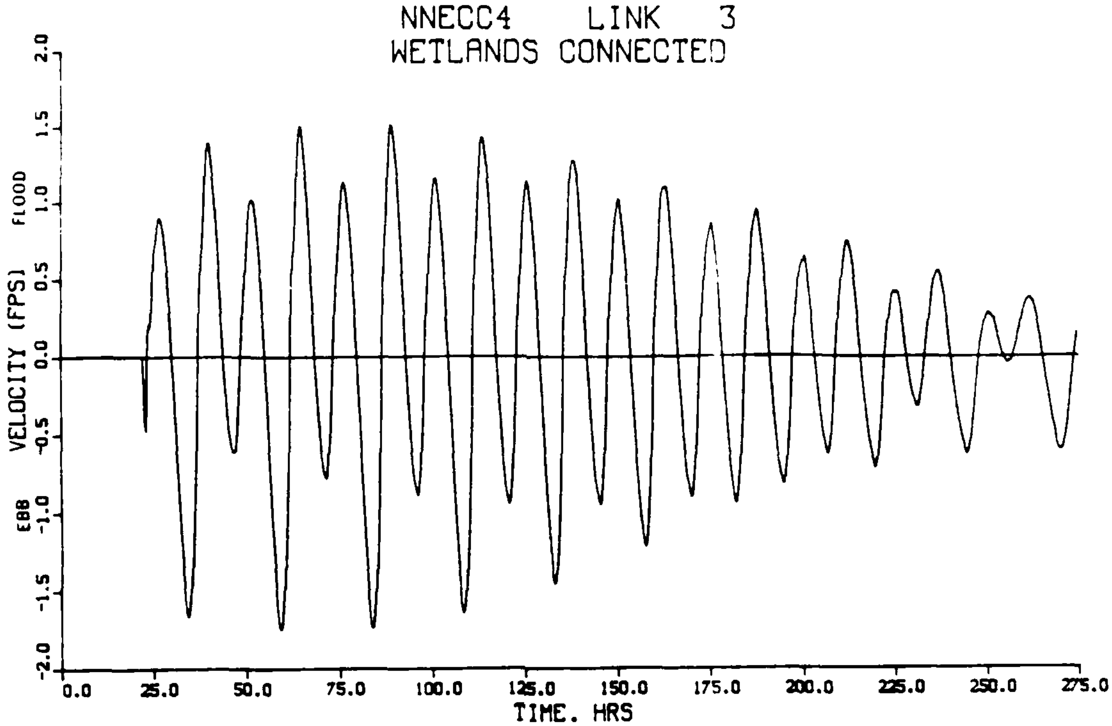


Figure J1. Average channel velocities in Huntington Harbour under non-navigable entrance, no by-pass connector channel to marina conditions

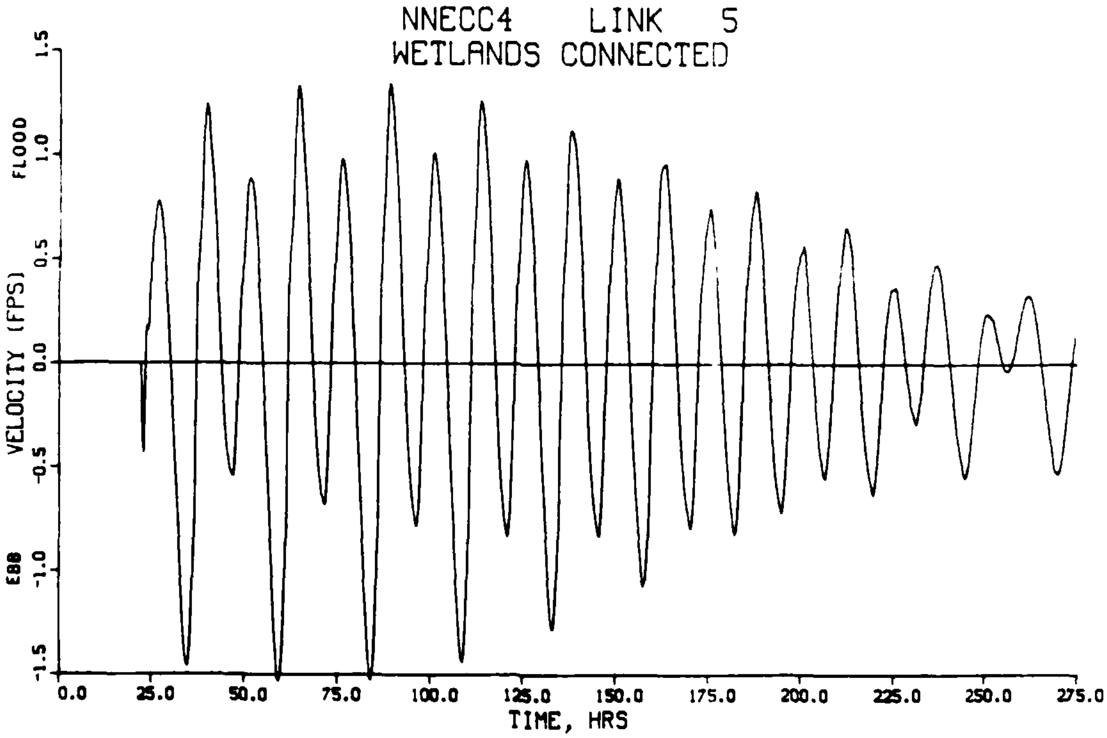


Figure J2. Average channel velocities in Huntington Harbour under non-navigable entrance, no by-pass connector channel to marina conditions

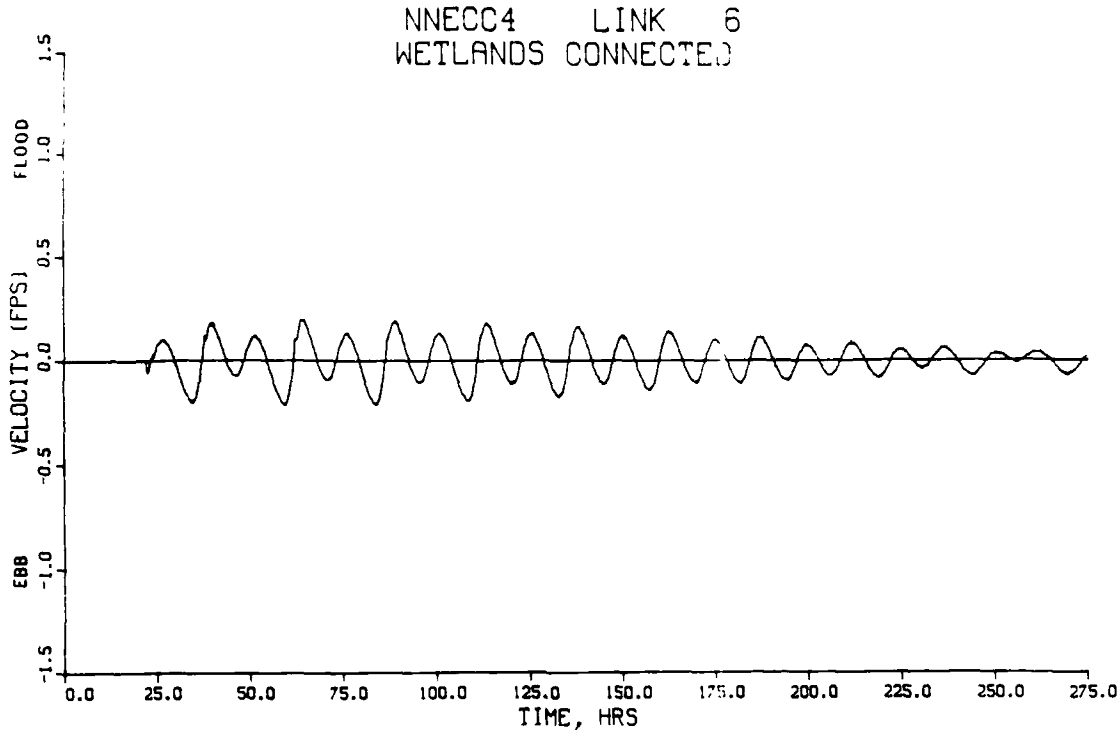


Figure J3. Average channel velocities in Huntington Harbour under non-navigable entrance, no by-pass connector channel to marina conditions

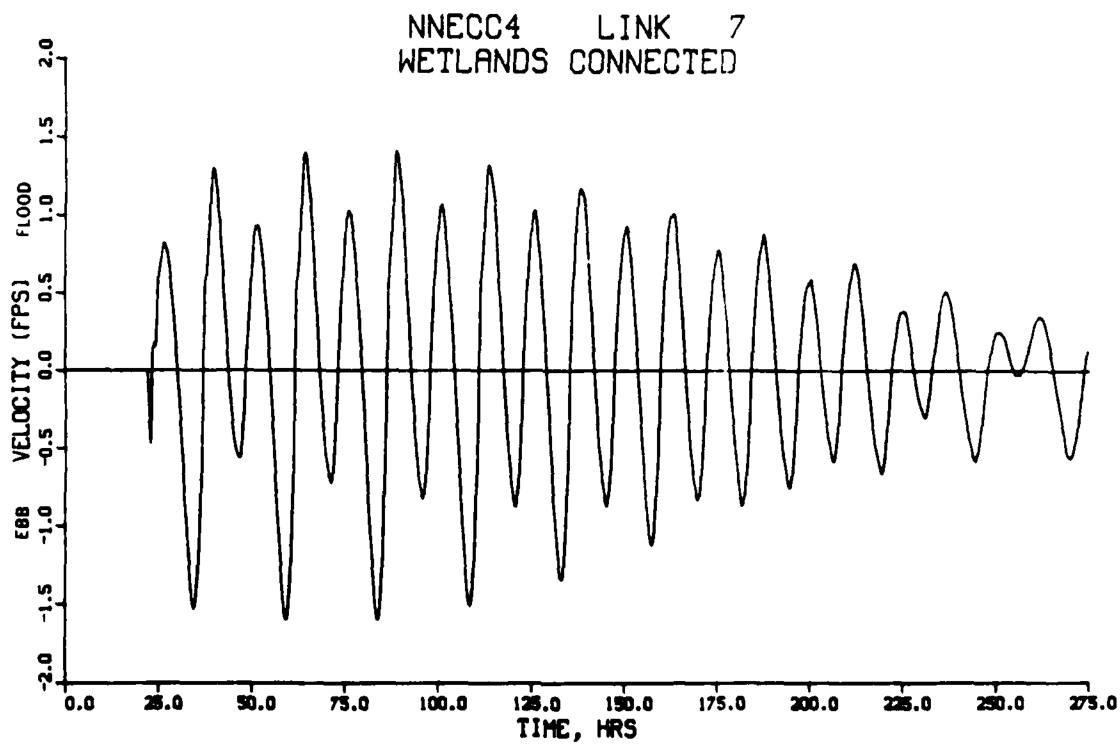


Figure J4. Average channel velocities in Huntington Harbour under non-navigable entrance, no by-pass connector channel to marina conditions

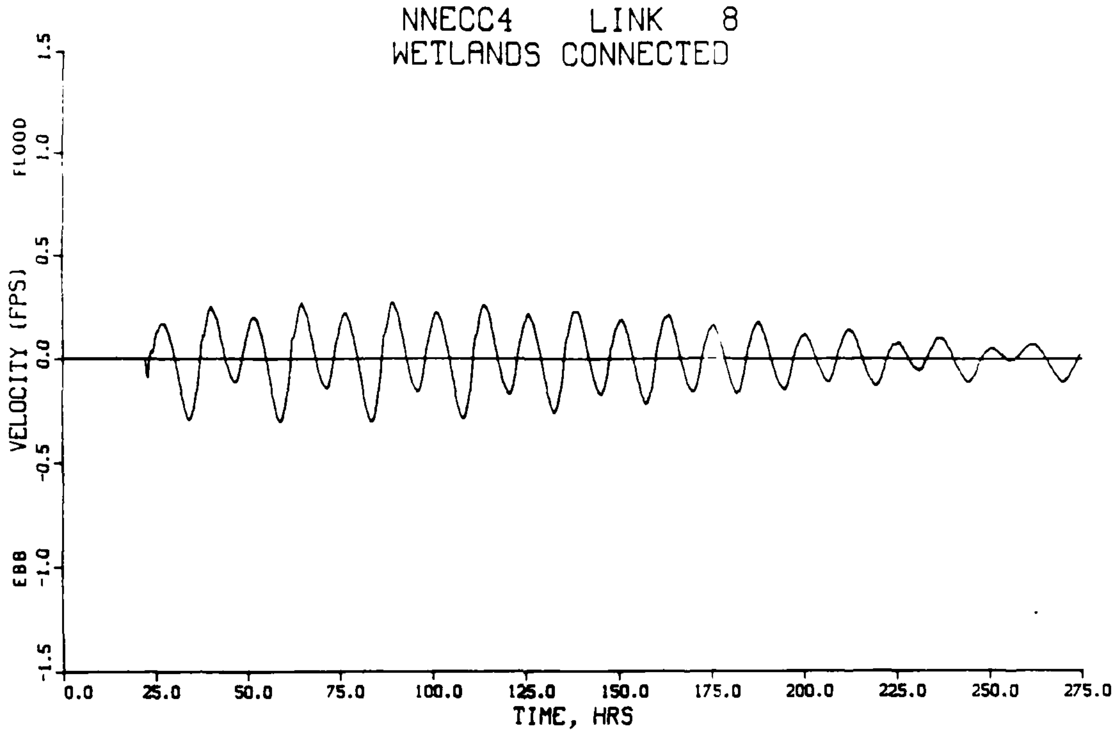


Figure J5. Average channel velocities in Huntington Harbour under non-navigable entrance, no by-pass connector channel to marina conditions

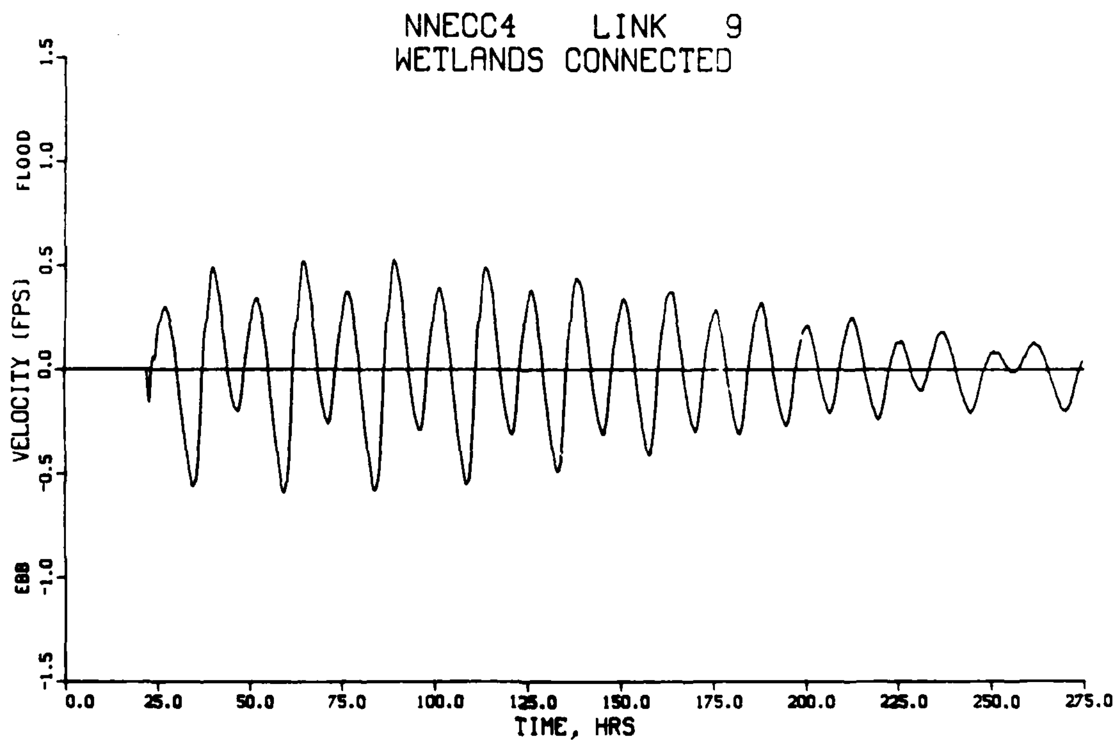


Figure J6. Average channel velocities in Huntington Harbour under non-navigable entrance, no by-pass connector channel to marina conditions

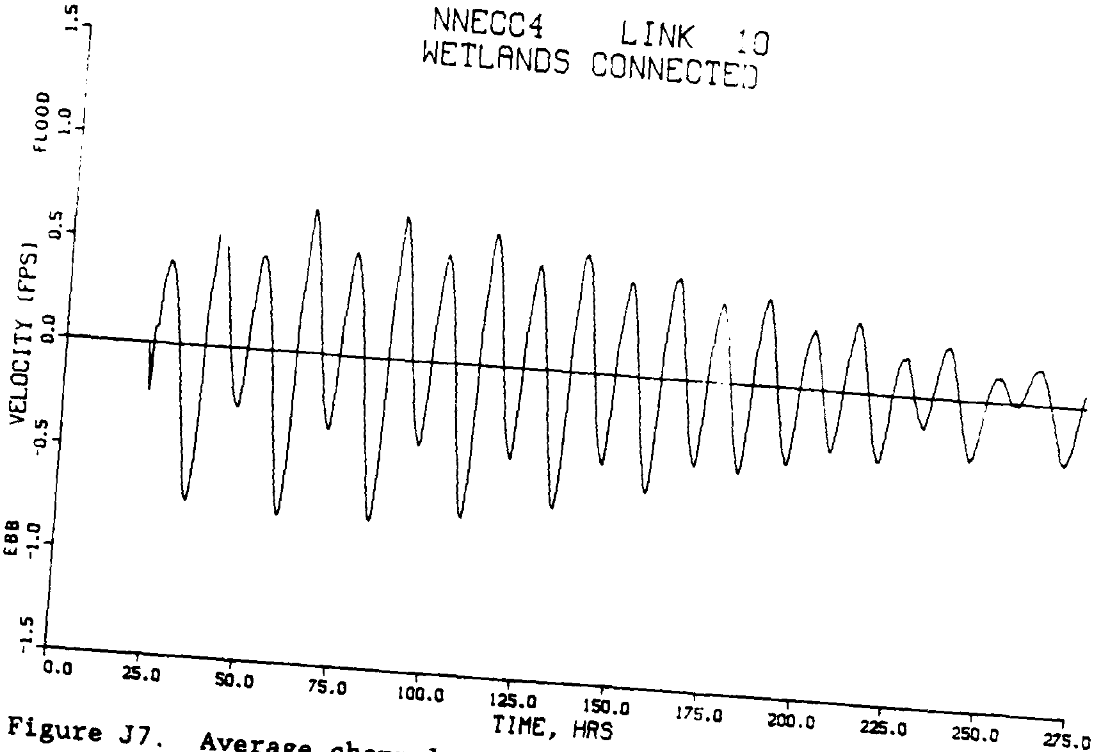


Figure J7. Average channel velocities in Huntington Harbour under non-navigable entrance, no by-pass connector channel to marina conditions

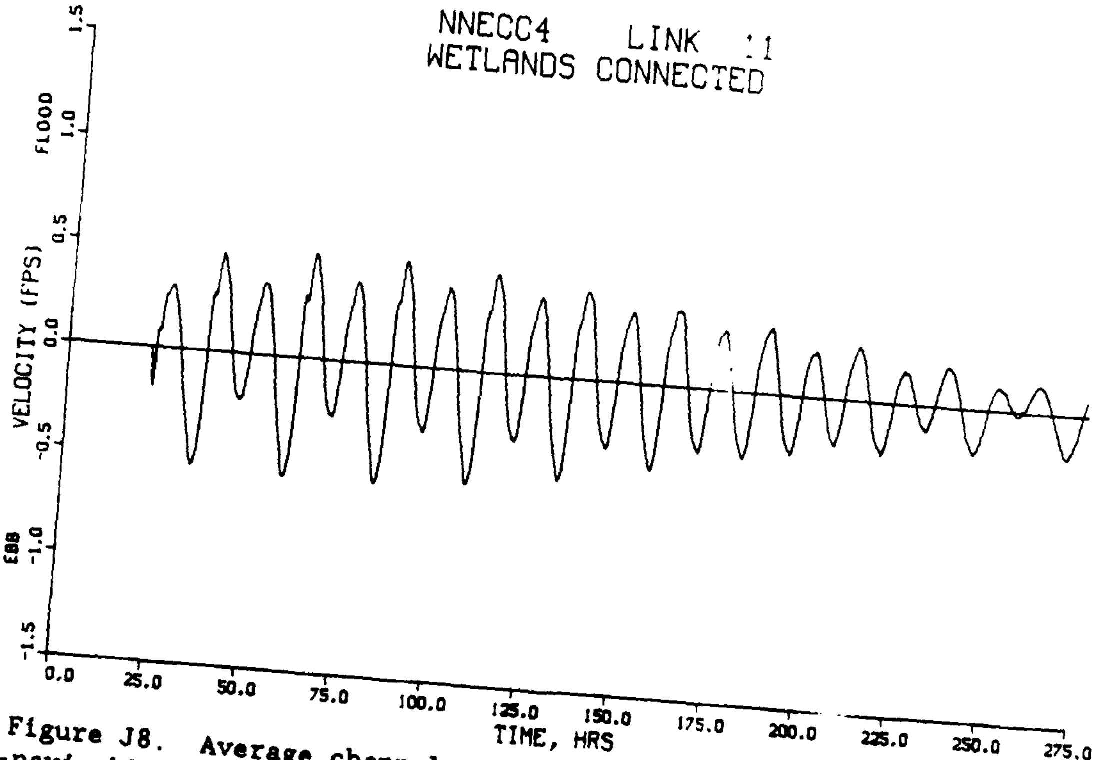


Figure J8. Average channel velocities in Huntington Harbour under non-navigable entrance, no by-pass connector channel to marina conditions

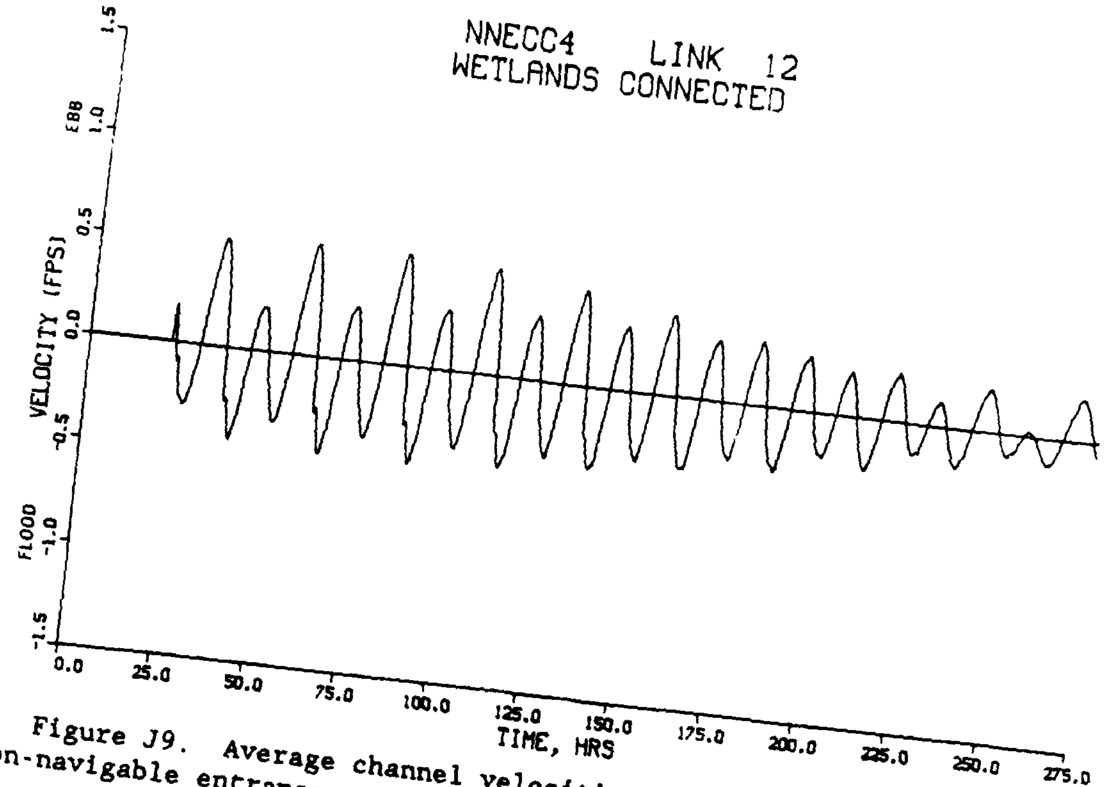


Figure J9. Average channel velocities in Huntington Harbour under non-navigable entrance, no by-pass connector channel to marina conditions

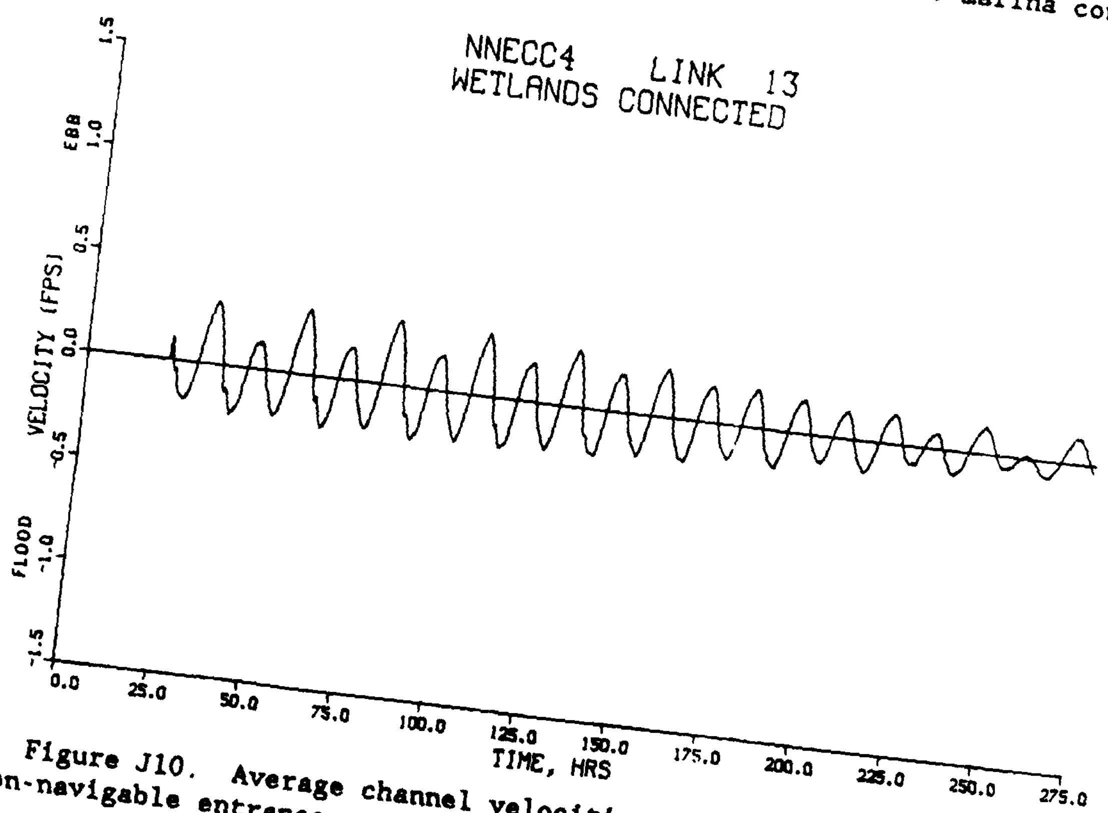


Figure J10. Average channel velocities in Huntington Harbour under non-navigable entrance, no by-pass connector channel to marina conditions

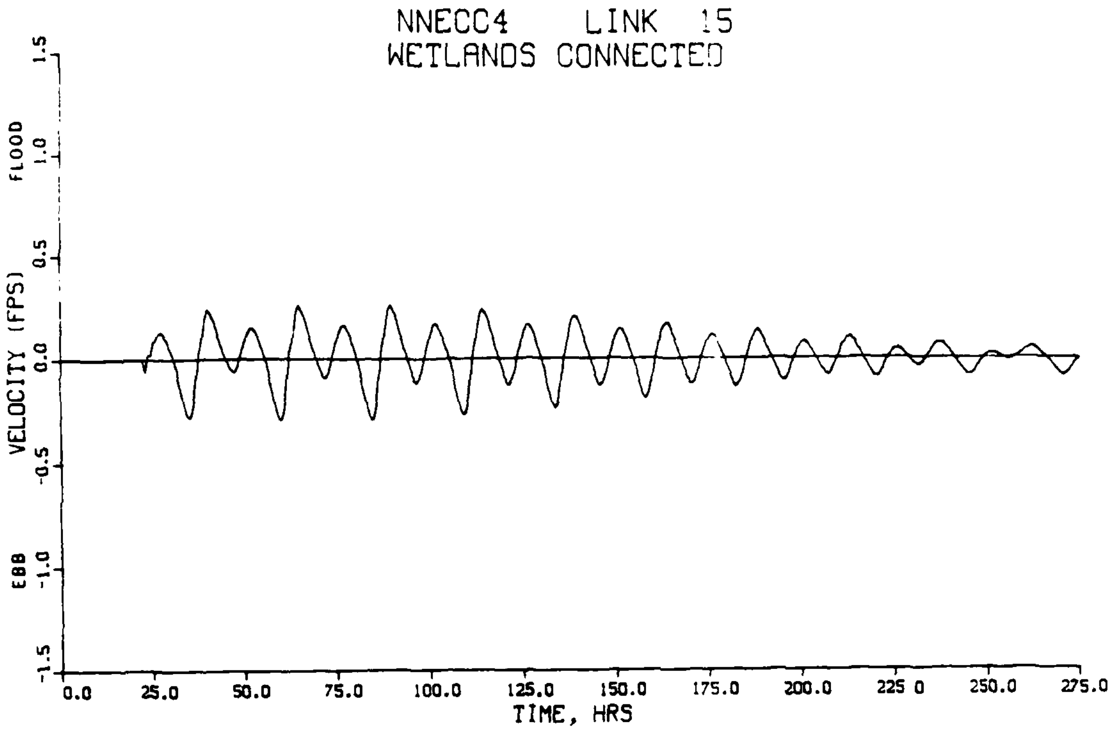


Figure J11. Average channel velocities in Huntington Harbour under non-navigable entrance, no by-pass connector channel to marina conditions

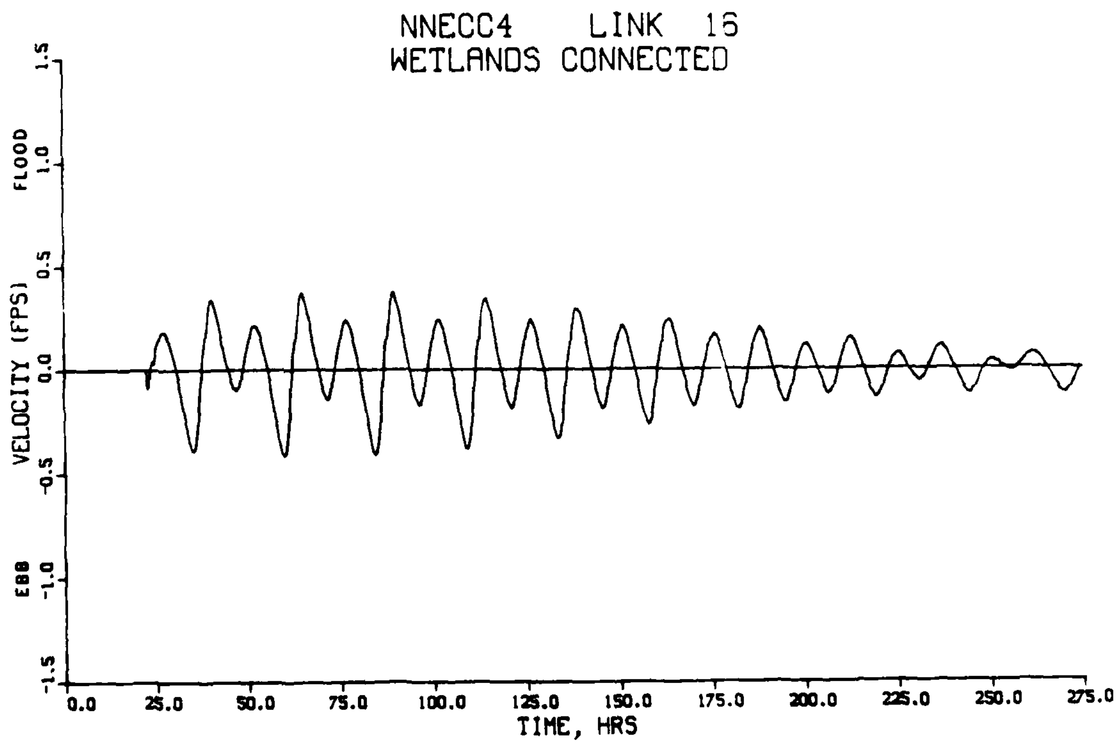


Figure J12. Average channel velocities in Huntington Harbour under non-navigable entrance, no by-pass connector channel to marina conditions

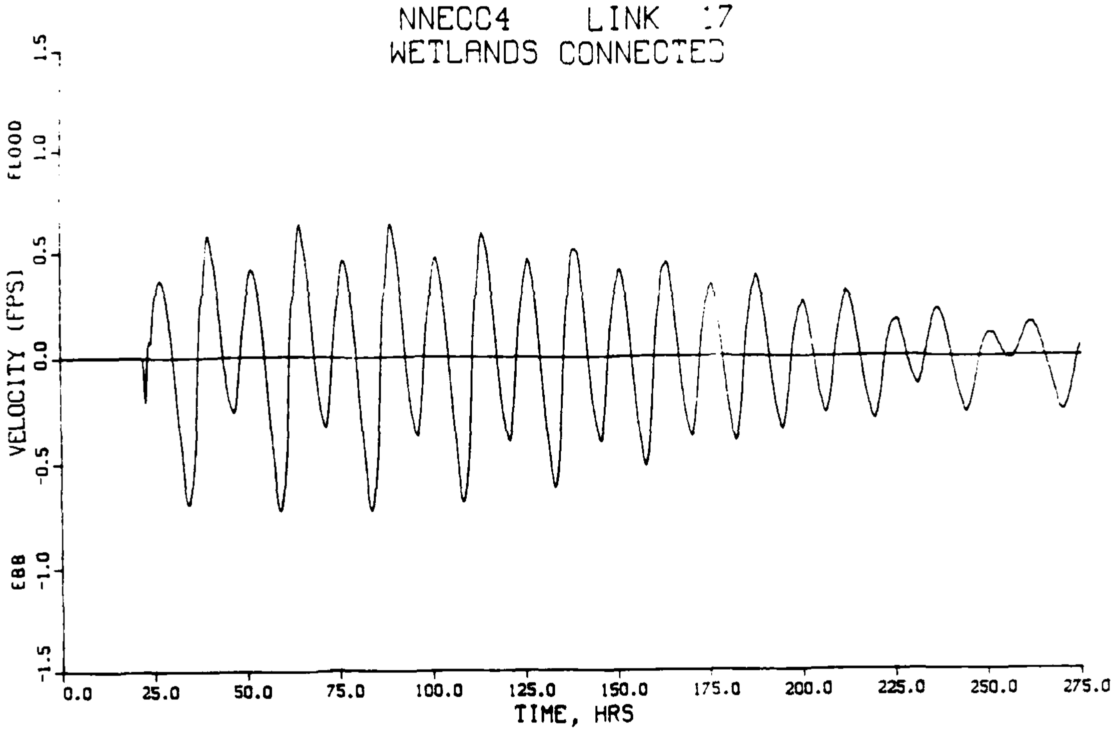


Figure J13. Average channel velocities in Huntington Harbour under non-navigable entrance, no by-pass connector channel to marina conditions

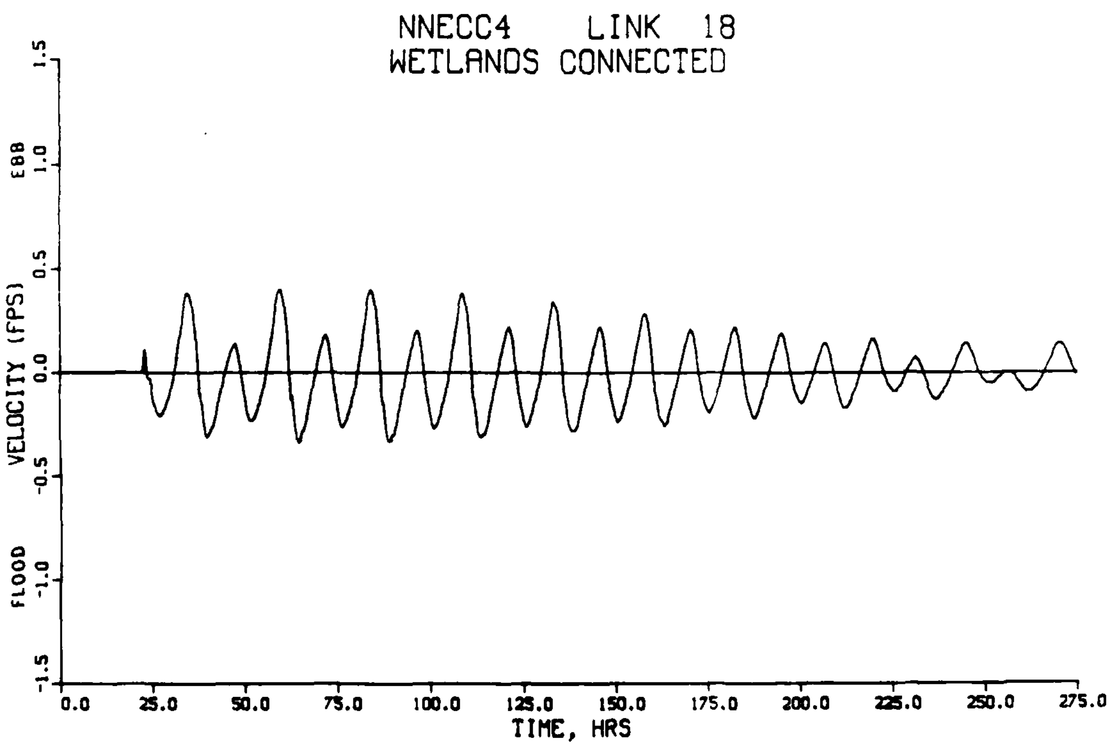


Figure J14. Average channel velocities in Huntington Harbour under non-navigable entrance, no by-pass connector channel to marina conditions

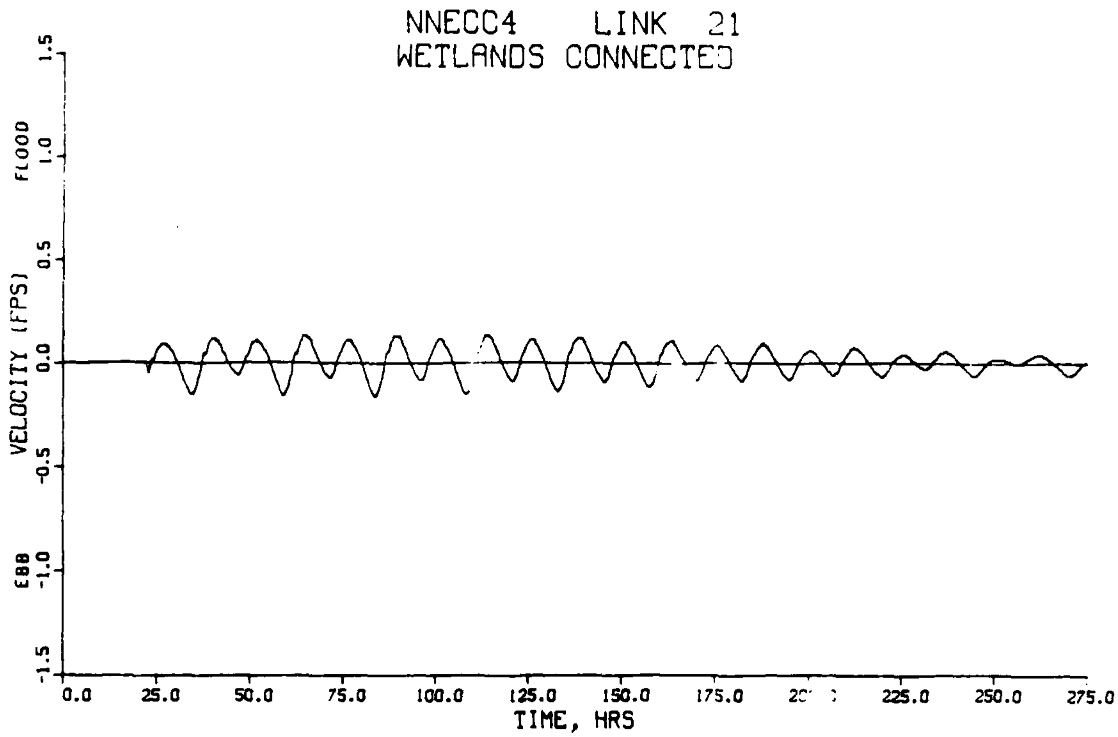


Figure J15. Average channel velocities in Huntington Harbour under non-navigable entrance, no by-pass connector channel to marina conditions

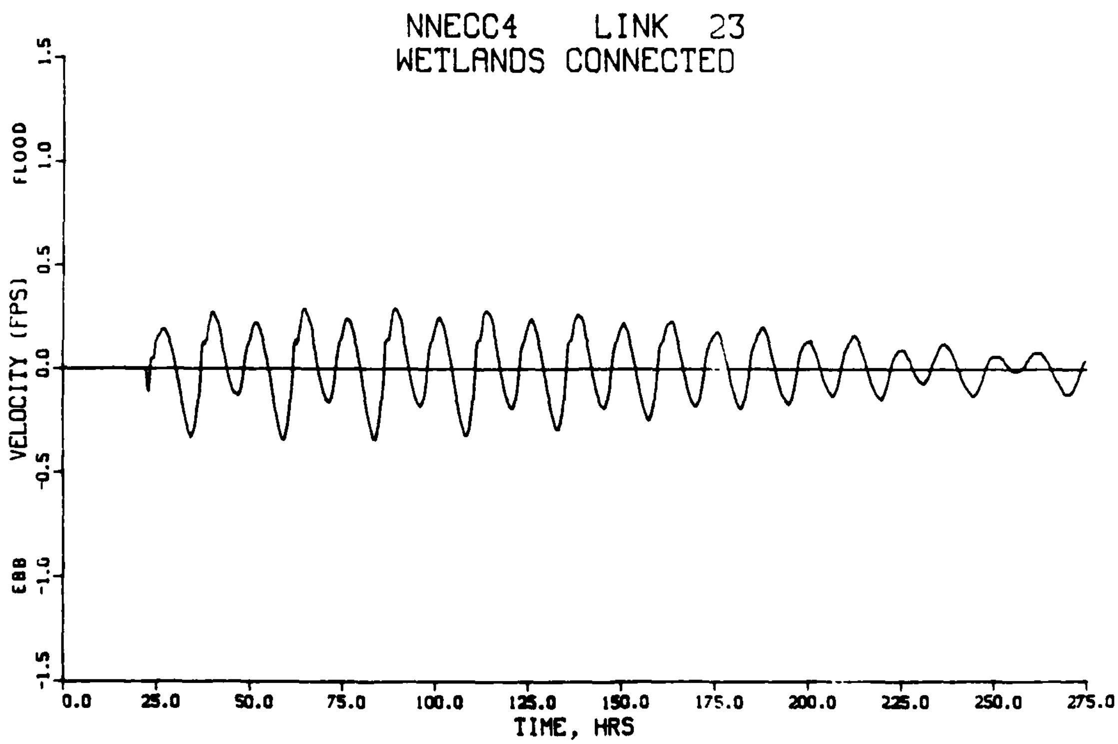


Figure J16. Average channel velocities in Huntington Harbour under non-navigable entrance, no by-pass connector channel to marina conditions

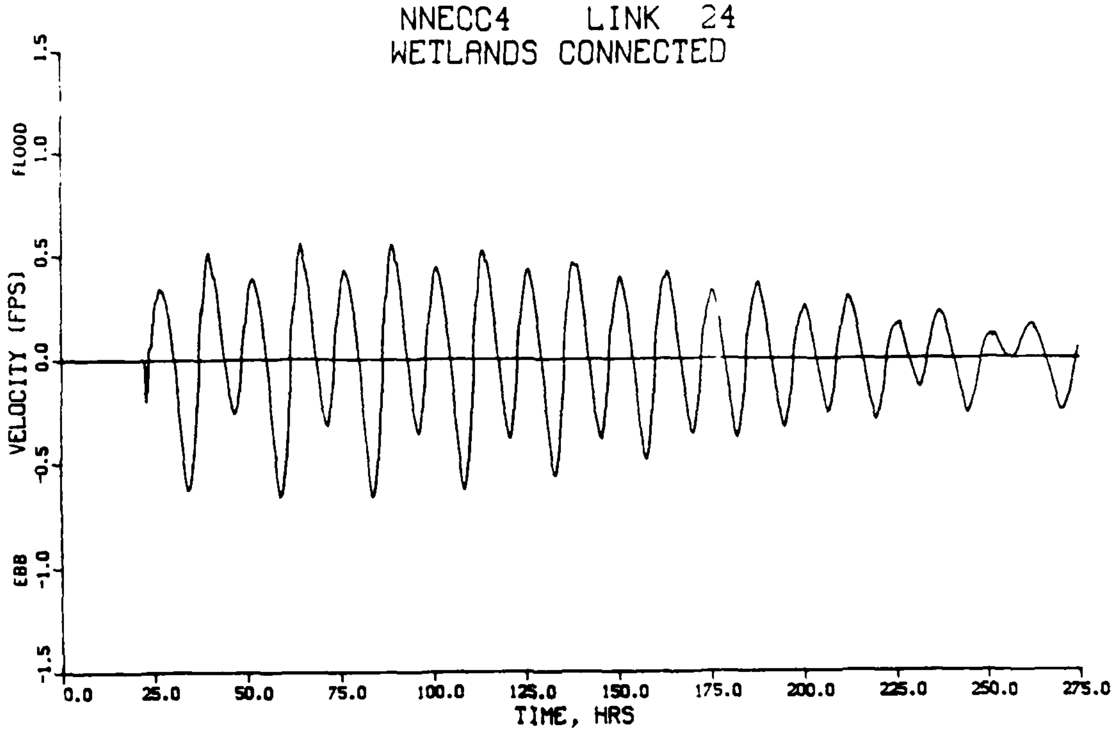


Figure J17. Average channel velocities in Huntington Harbour under non-navigable entrance, no by-pass connector channel to marina conditions

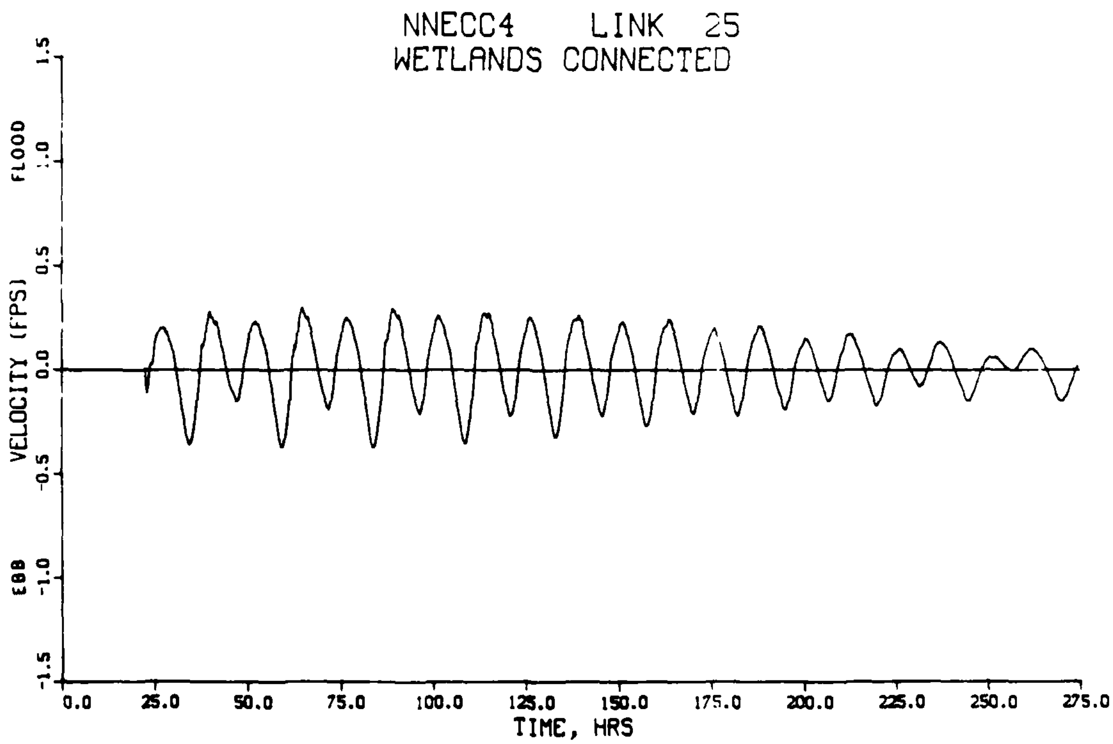


Figure J18. Average channel velocities in Huntington Harbour under non-navigable entrance, no by-pass connector channel to marina conditions

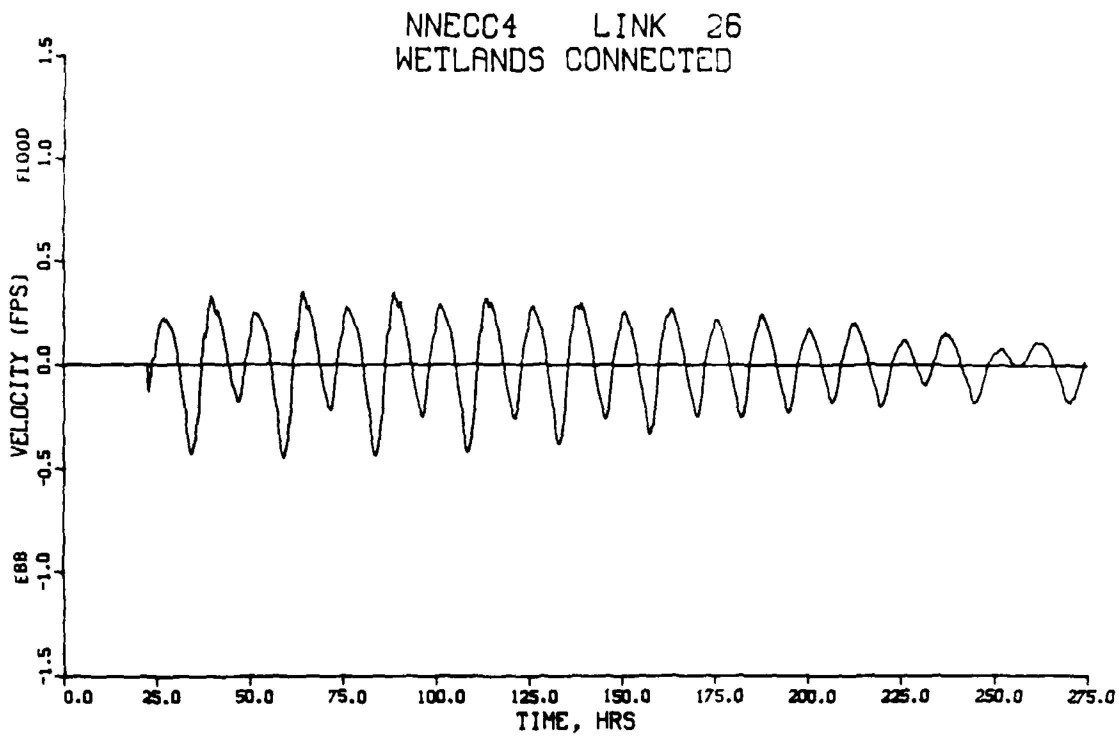


Figure J19. Average channel velocities in Huntington Harbour under non-navigable entrance, no by-pass connector channel to marina conditions

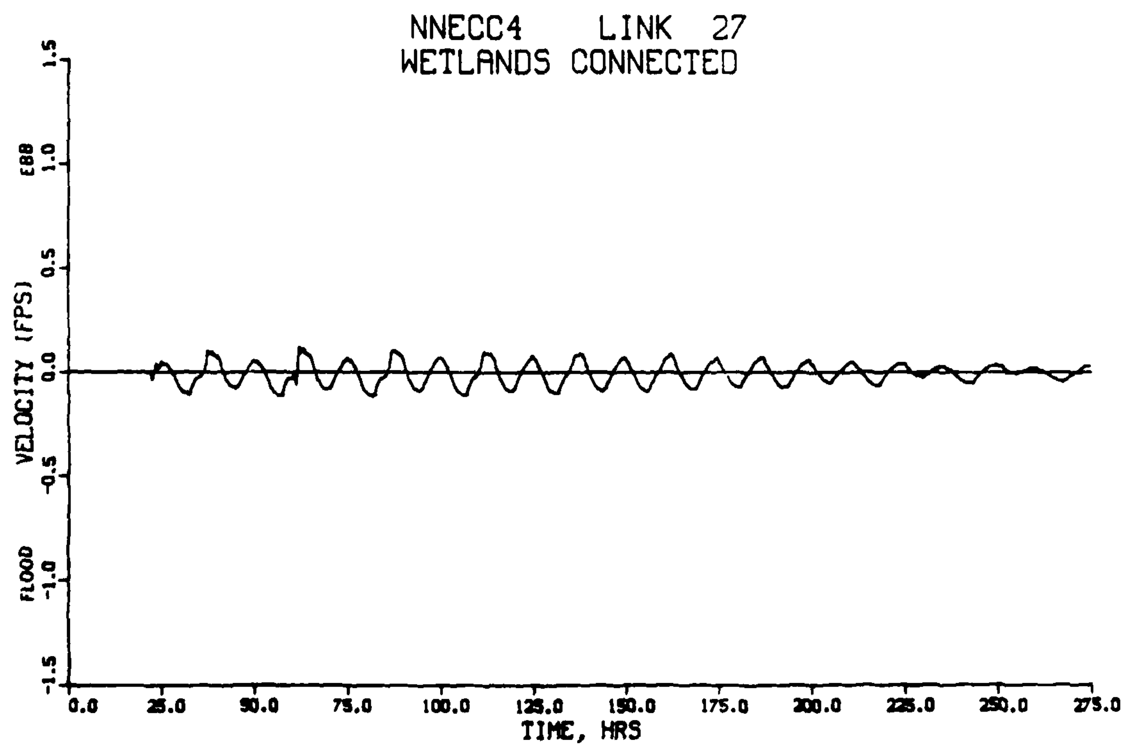


Figure J20. Average channel velocities in Huntington Harbour under non-navigable entrance, no by-pass connector channel to marina conditions

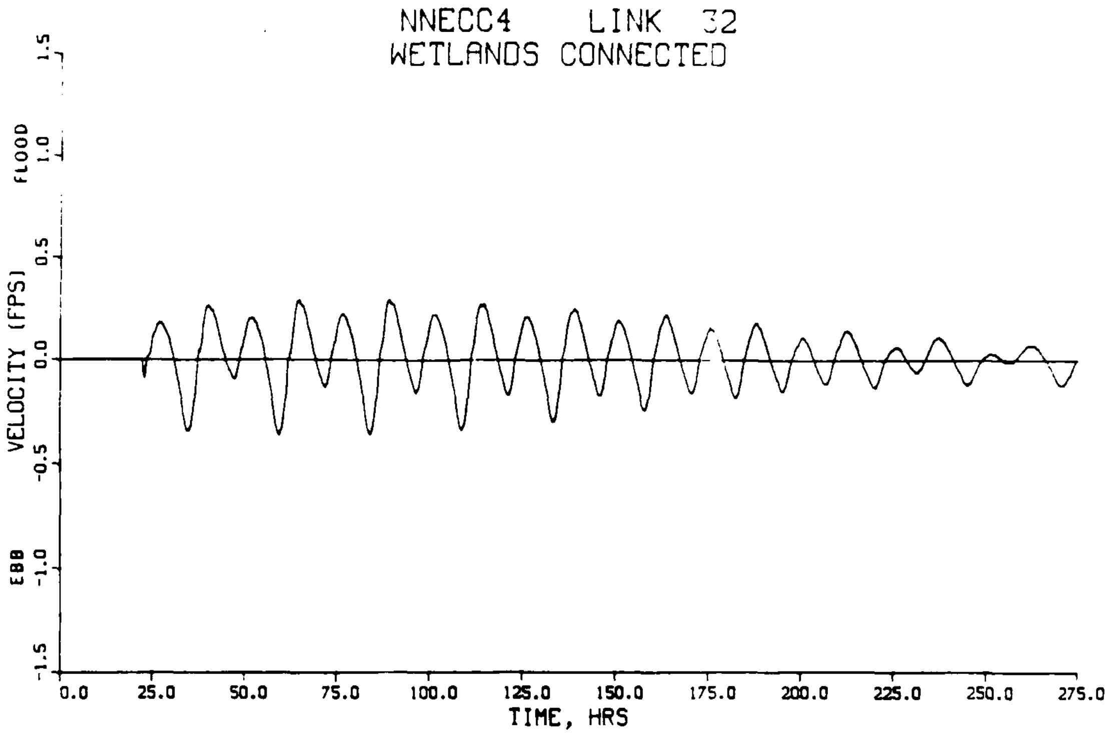


Figure J21. Average channel velocities in Huntington Harbour under non-navigable entrance, no by-pass connector channel to marina conditions

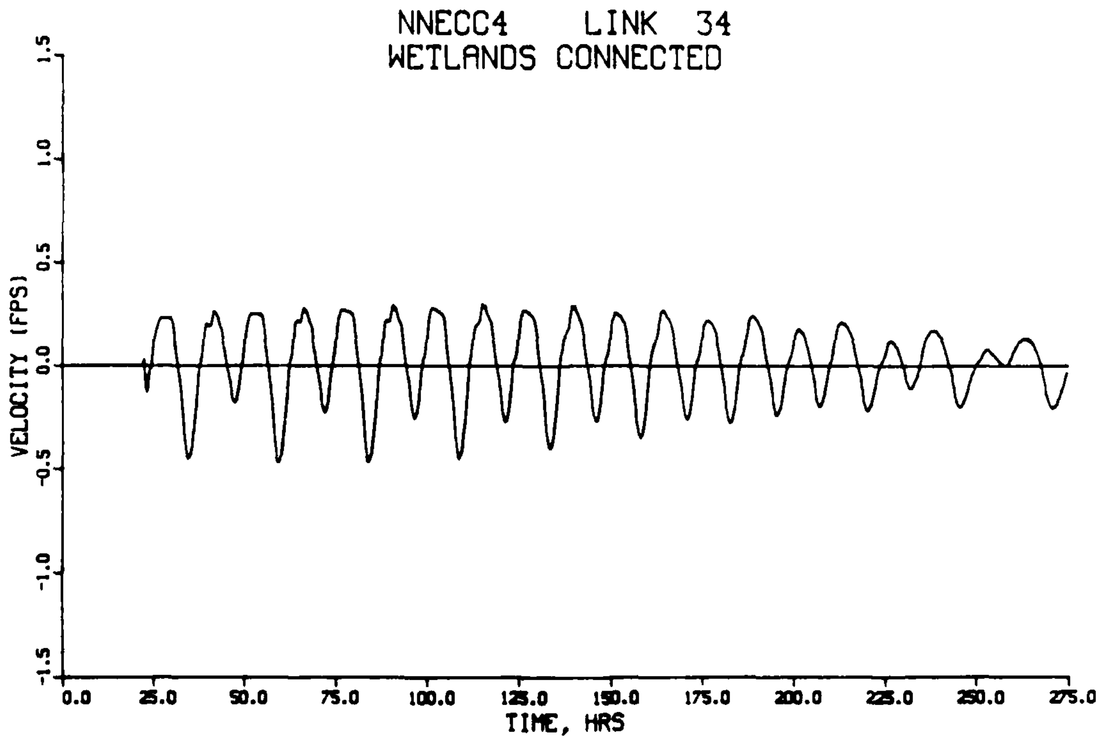


Figure J22. Average channel velocities at previous Warner Avenue under non-navigable entrance, no by-pass connector channel to marina conditions

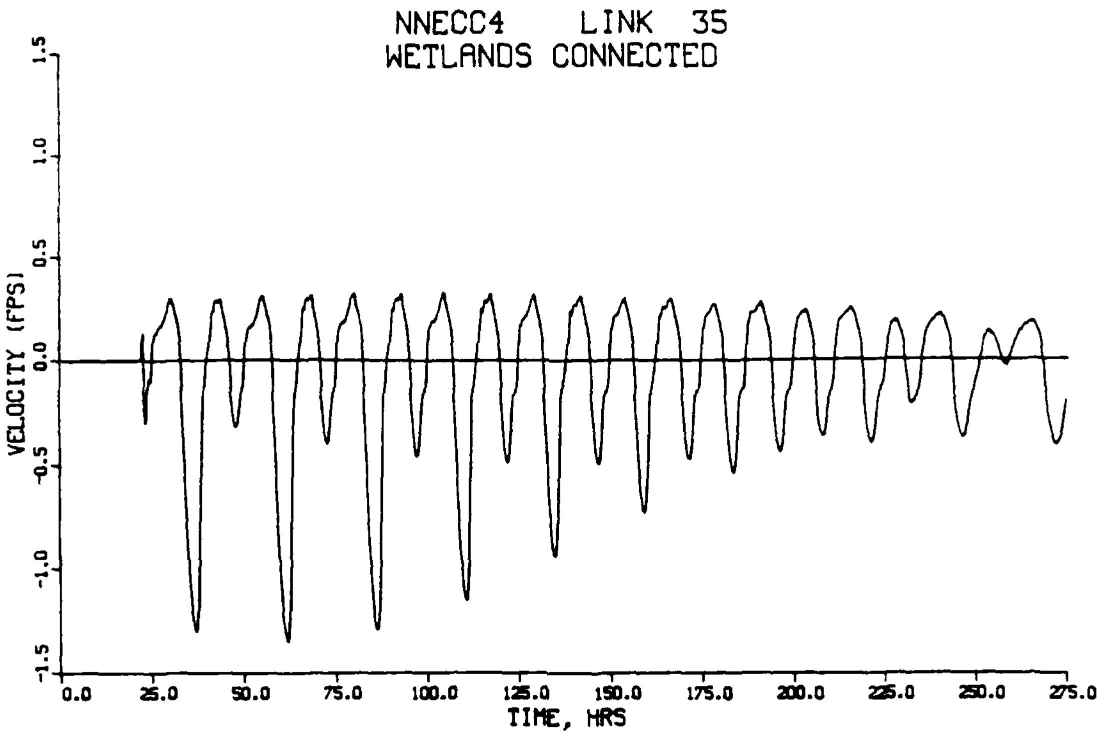


Figure J23. Average channel velocities in Outer Bolsa Bay under non-navigable entrance, no by-pass connector channel to marina conditions

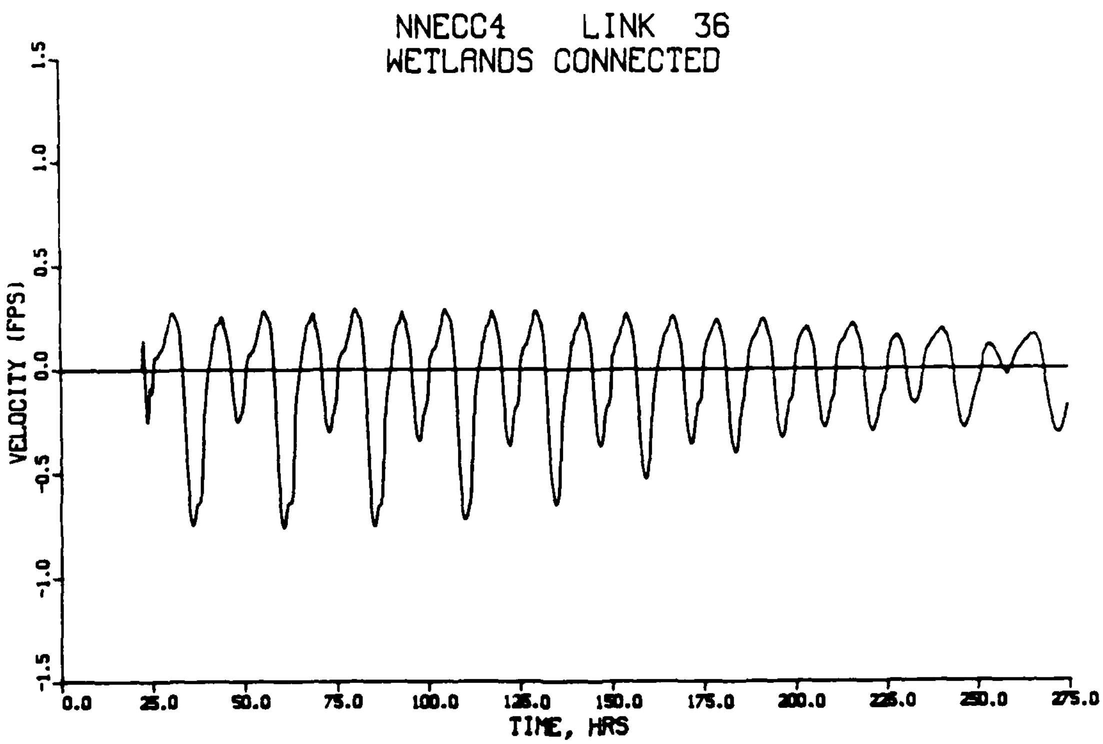


Figure J24. Average channel velocities in Outer Bolsa Bay under non-navigable entrance, no by-pass connector channel to marina conditions

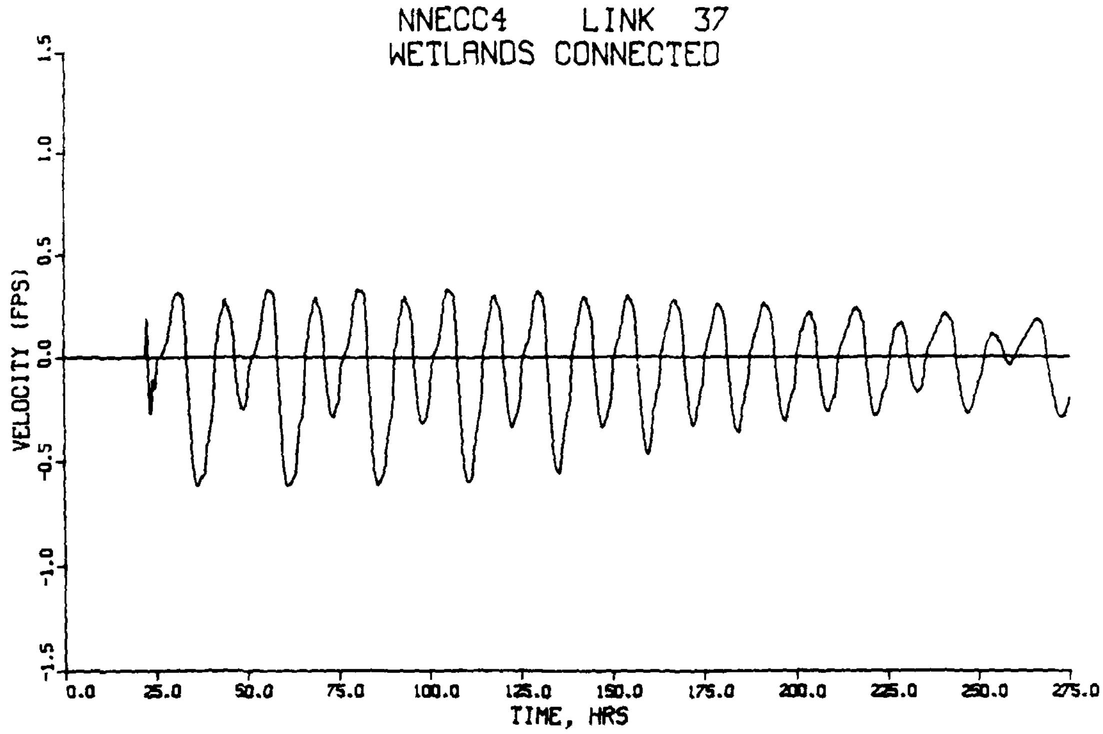


Figure J25. Average channel velocities in Outer Bolsa Bay under non-navigable entrance, no by-pass connector channel to marina conditions

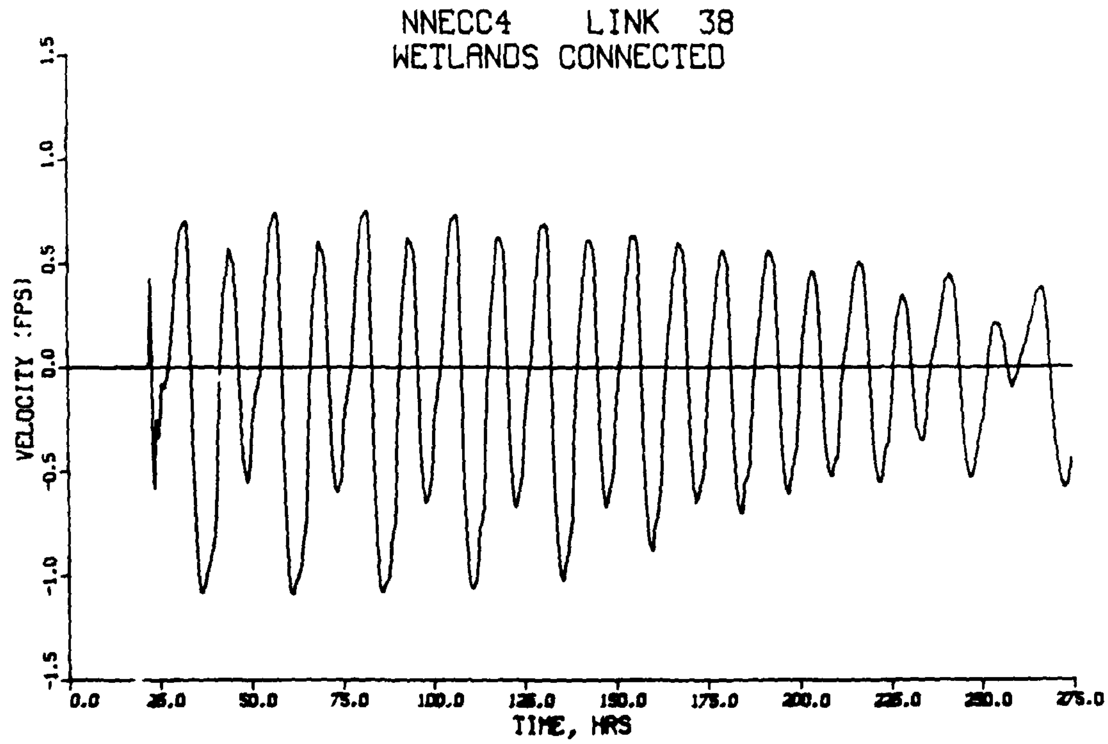


Figure J26. Average channel velocities in Outer Bolsa Bay under non-navigable entrance, no by-pass connector channel to marina conditions

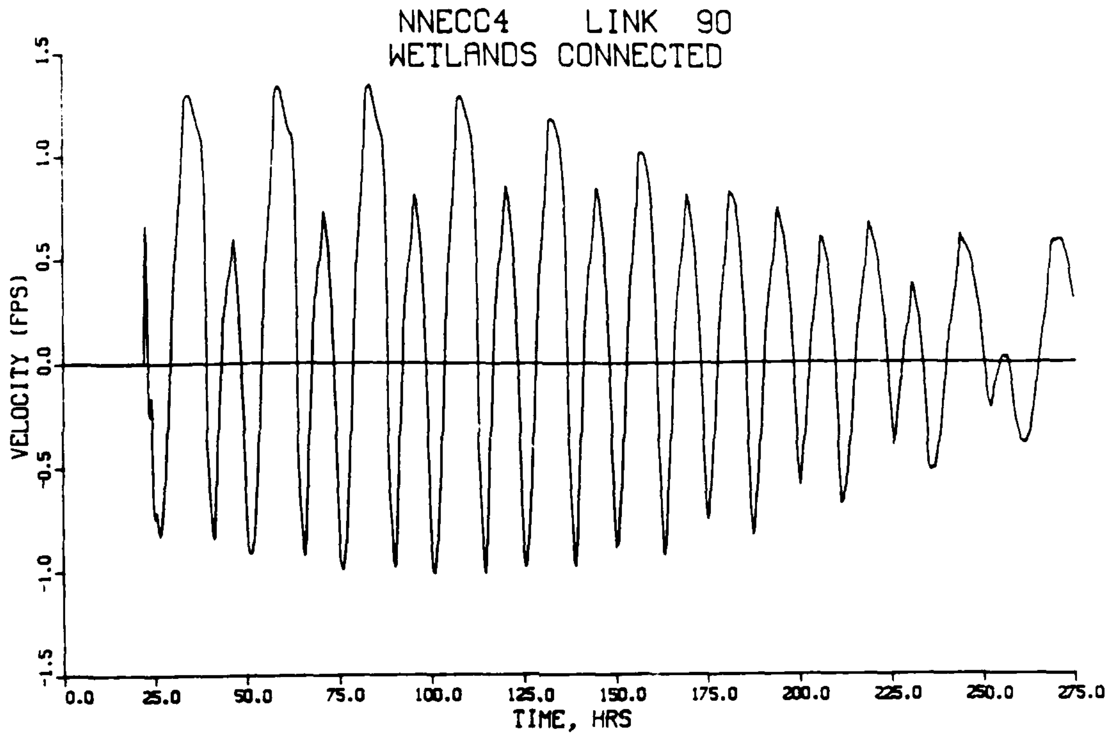


Figure J27. Average channel velocities in entrance channel under non-navigable entrance, no by-pass connector channel to marina conditions

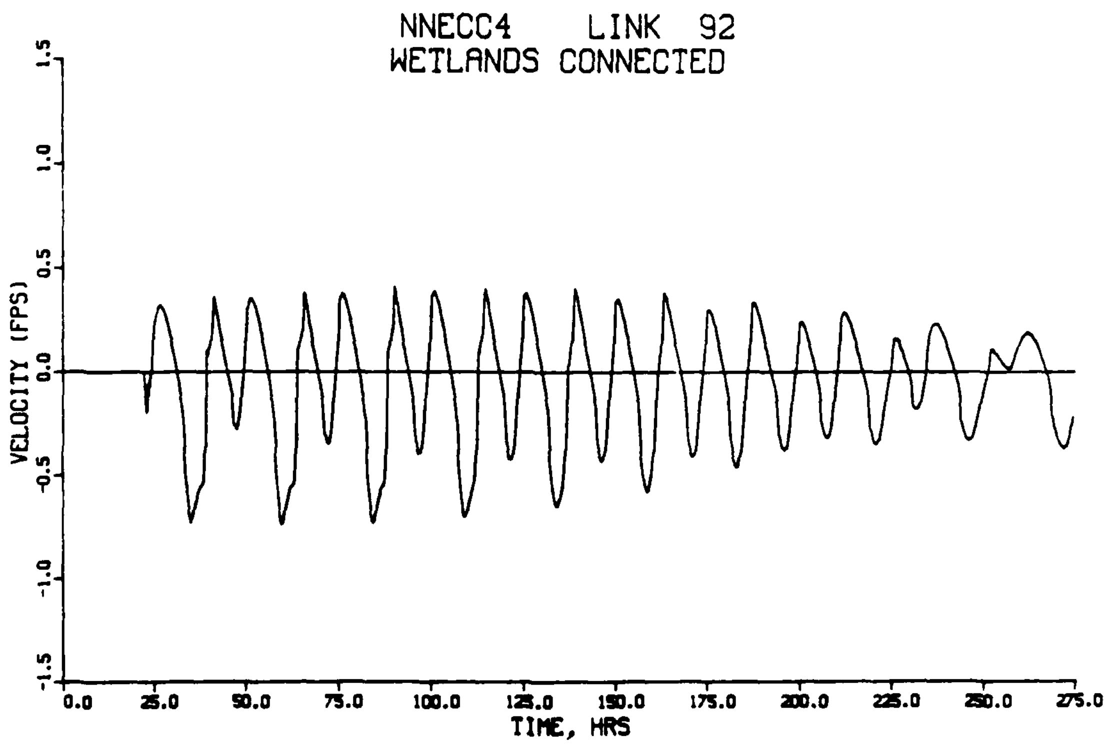


Figure J28. Average channel velocities in EGG-WFCC under non-navigable entrance, no by-pass connector channel to marina conditions

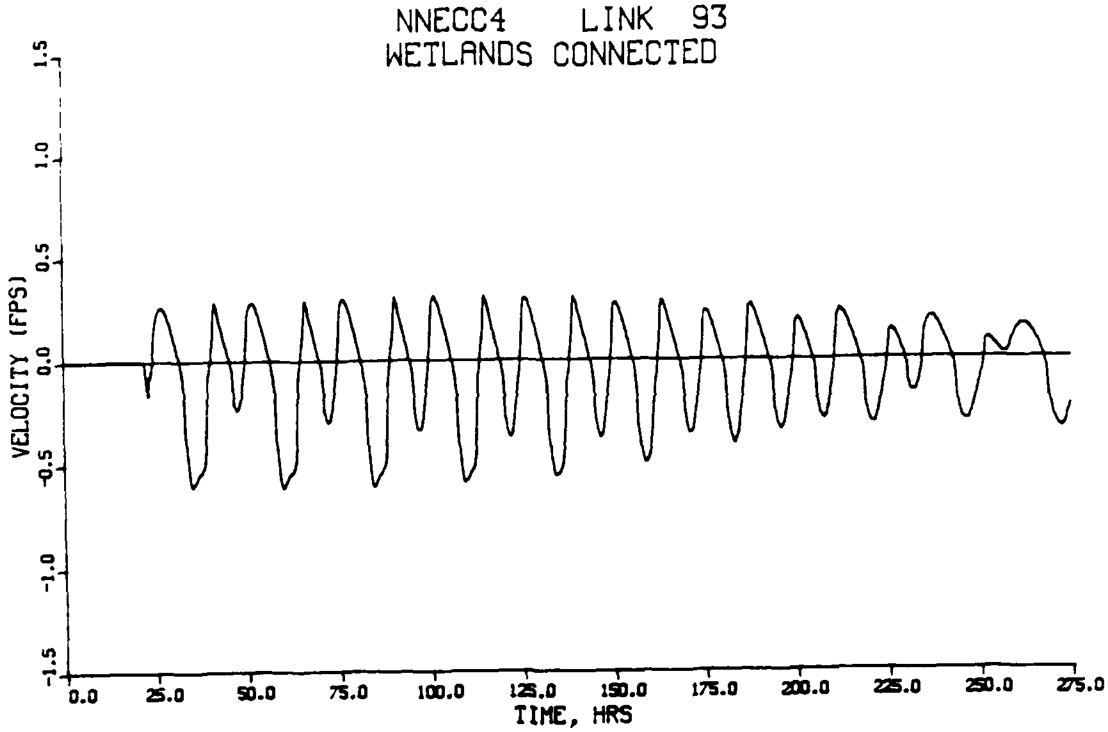


Figure J29. Average channel velocities in EGG-WFCC under non-navigable entrance, no by-pass connector channel to marina conditions

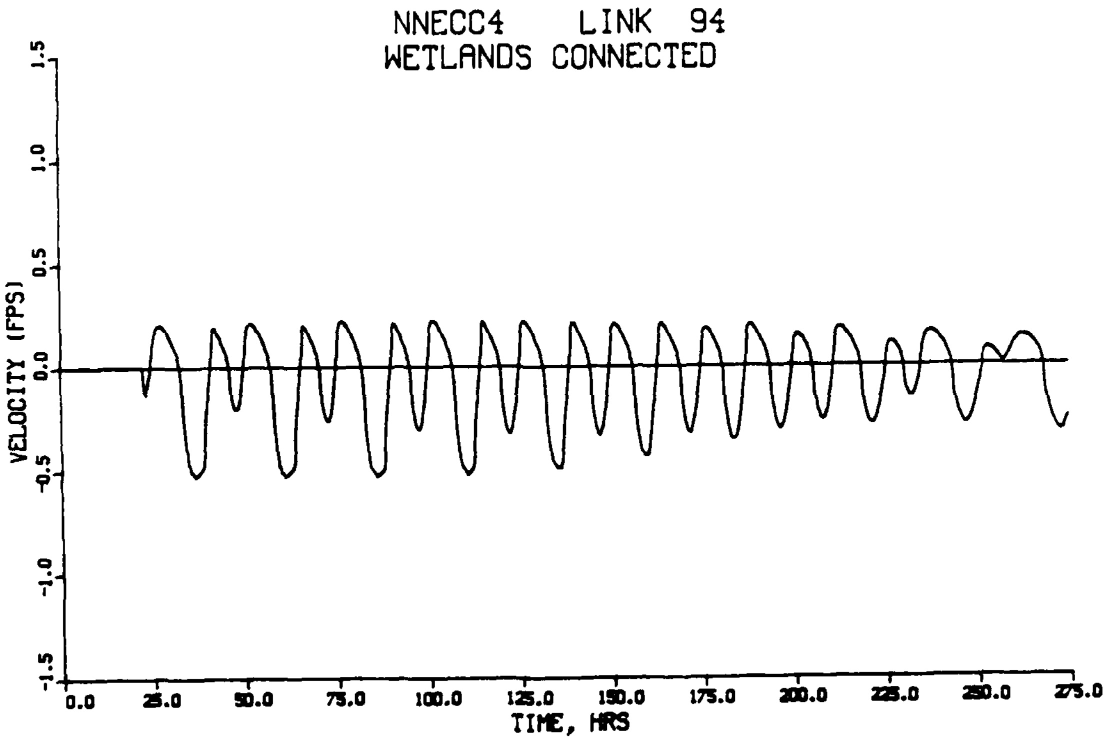


Figure J30. Average channel velocities in EGG-WFCC under non-navigable entrance, no by-pass connector channel to marina conditions

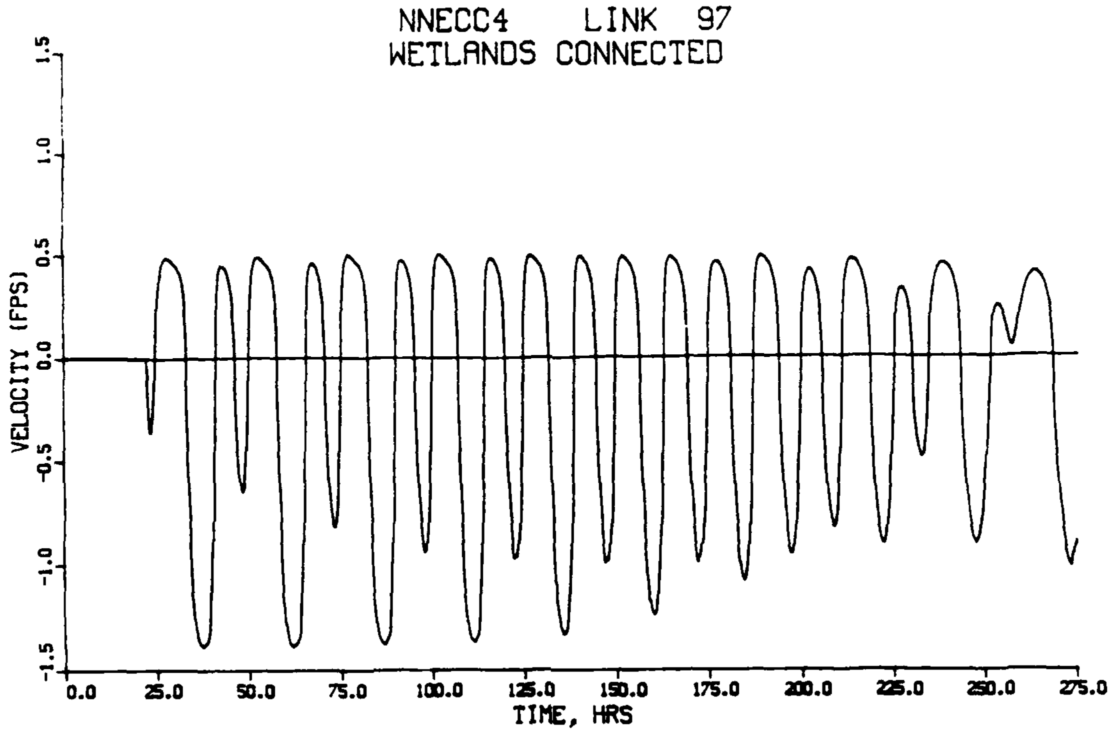


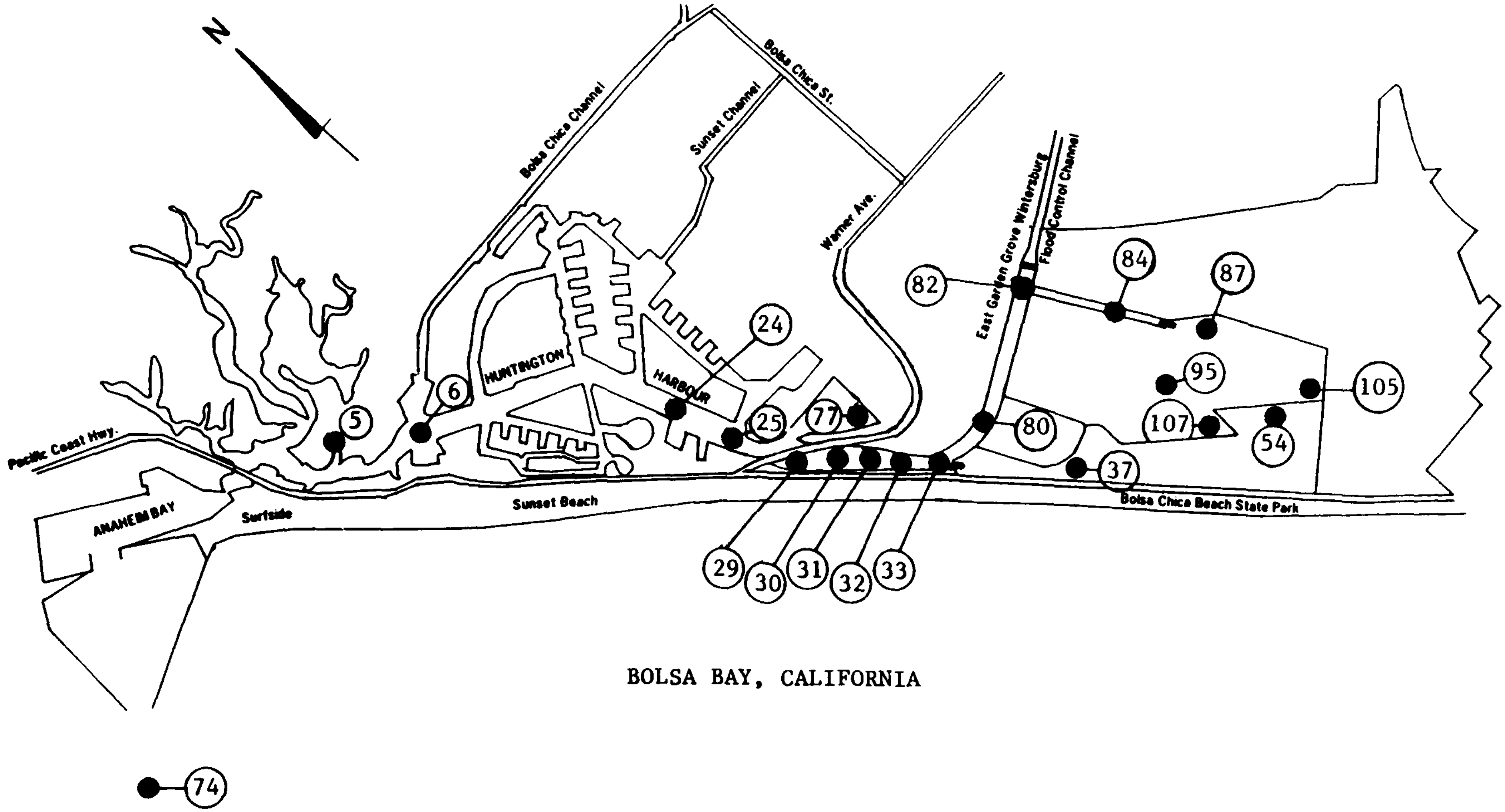
Figure J31. Average channel velocities in channel to muted wetlands under non-navigable entrance, no by-pass connector channel to marina conditions

APPENDIX K:

NOENT3

NON-NAVIGABLE ENTRANCE CHANNEL CLOSED
AND
NO BY-PASS CONNECTOR CHANNEL TO MARINA

WATER SURFACE ELEVATIONS



BOLSA BAY, CALIFORNIA

NOENT3
Location of nodes for displaying water surface elevations
under non-navigable entrance channel closed and no by-pass connector channel to marina conditions

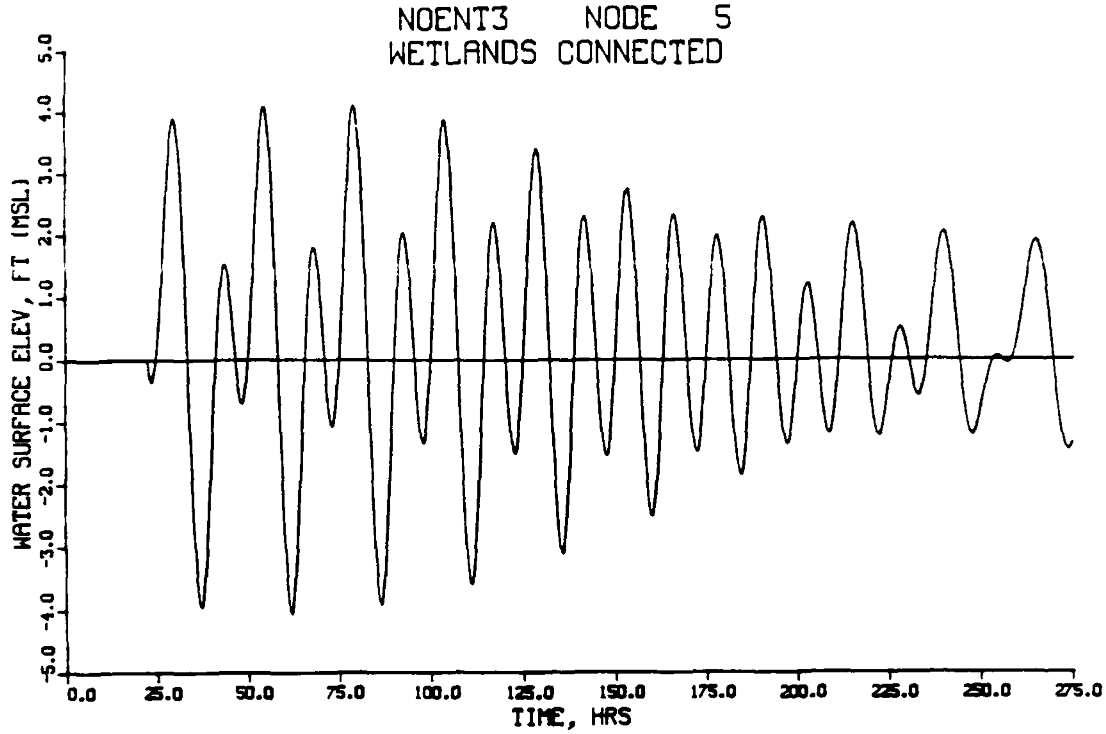


Figure K1. Tidal elevations in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

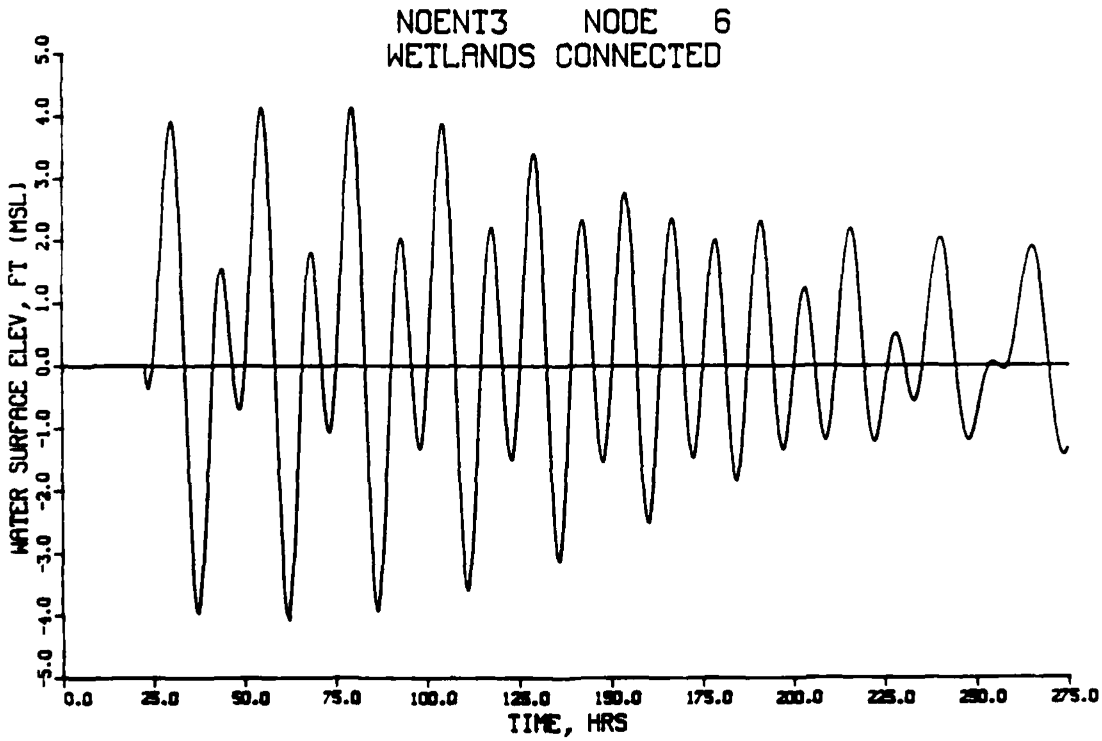


Figure K2. Tidal elevations in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

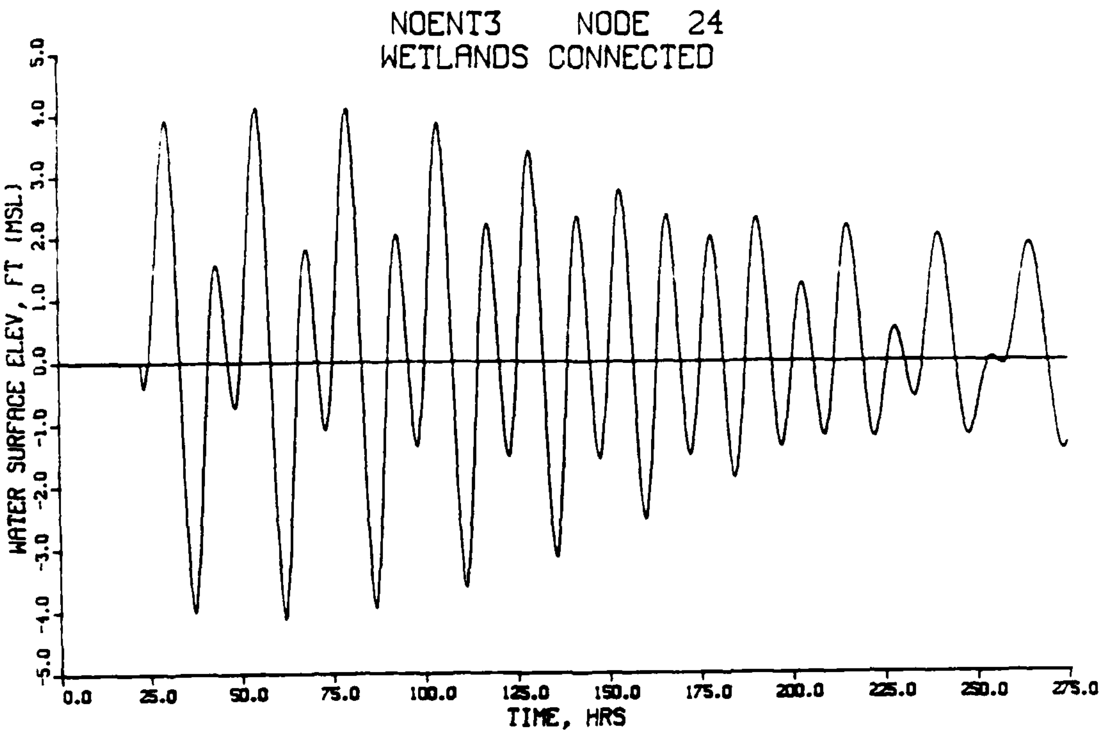


Figure K3. Tidal elevations in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

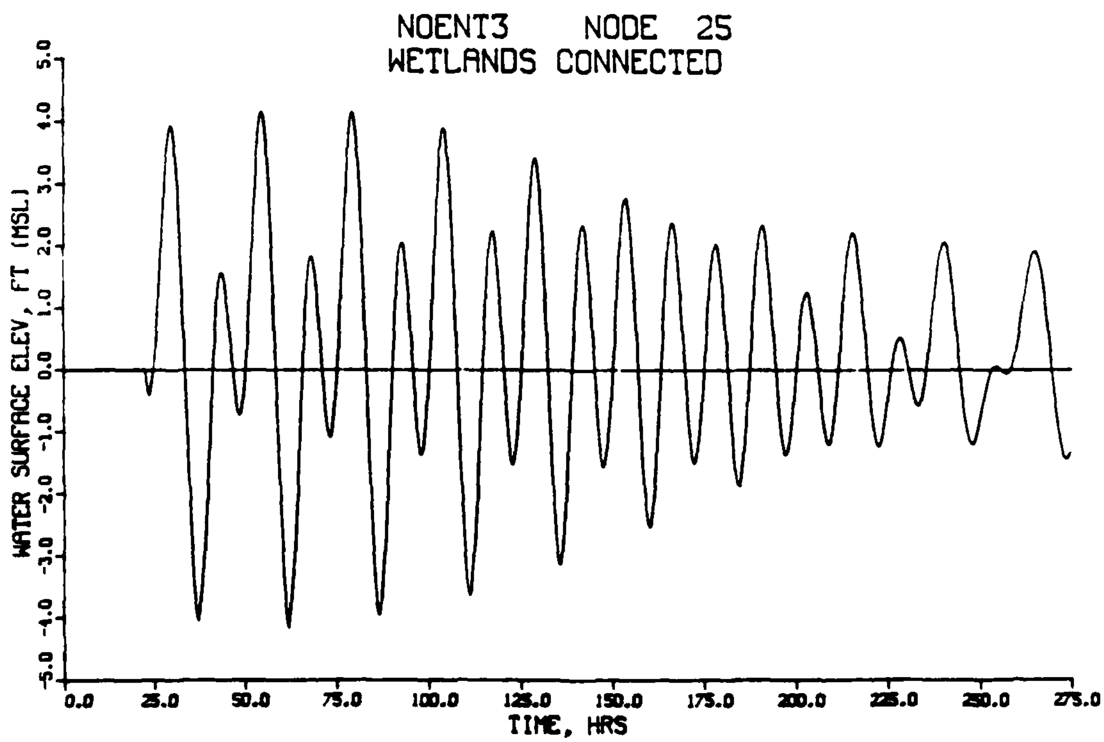


Figure K4. Tidal elevations in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

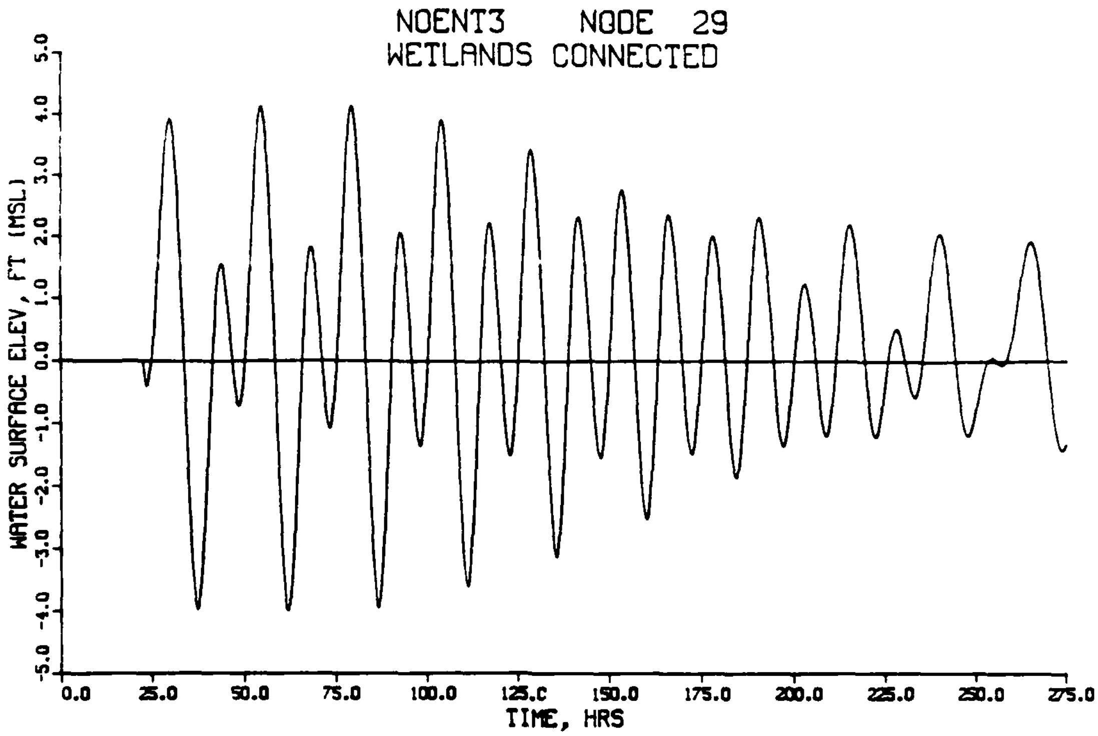


Figure K5. Tidal elevations in Outer Bolsa Bay under non-navigable entrance closed, no by-pass connector to marina conditions

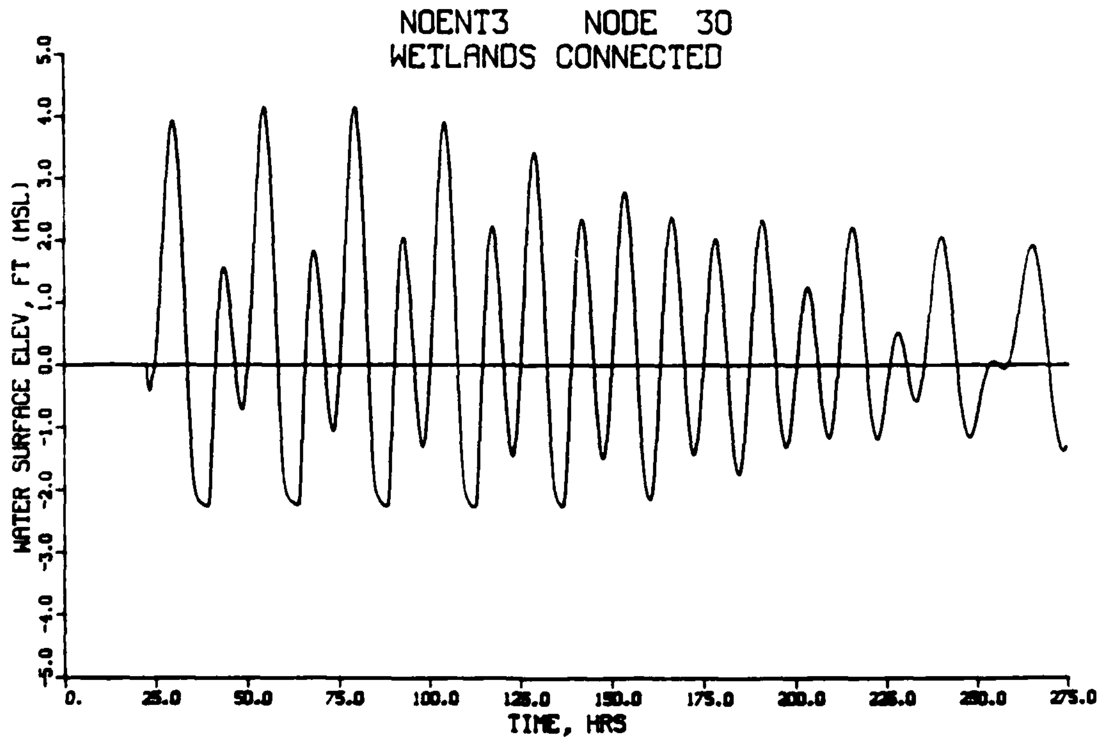


Figure K6. Tidal elevations in Outer Bolsa Bay under non-navigable entrance closed, no by-pass connector to marina conditions

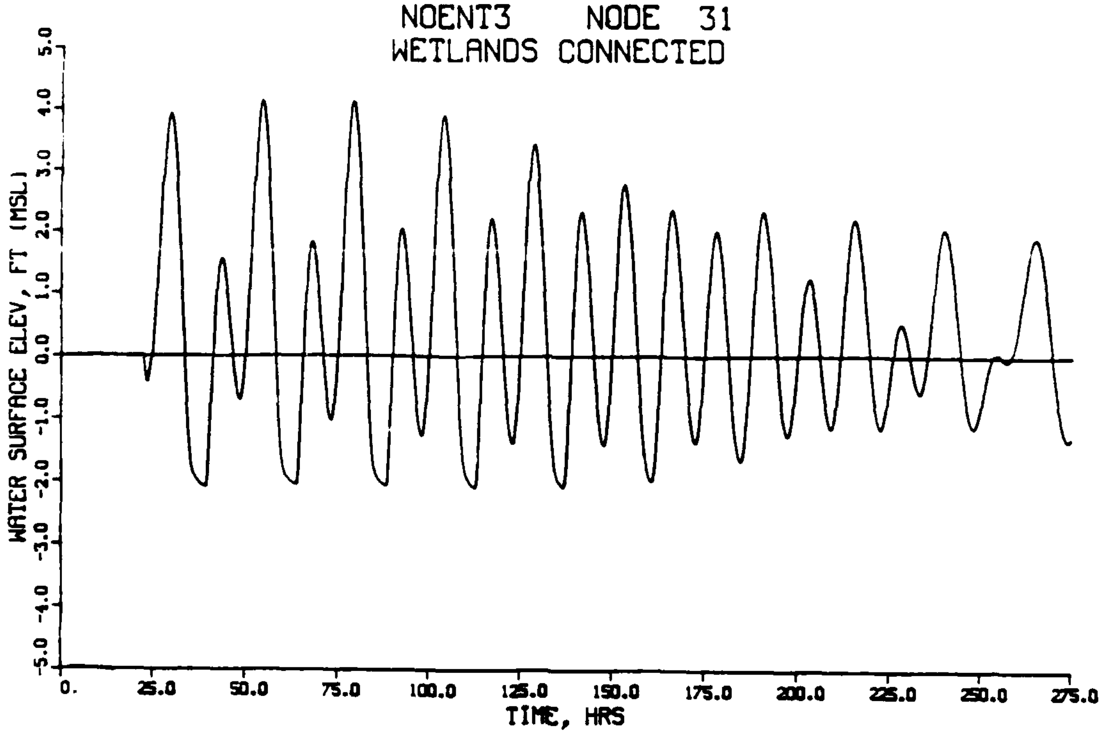


Figure K7. Tidal elevations in Outer Bolsa Bay under non-navigable entrance closed, no by-pass connector to marina conditions

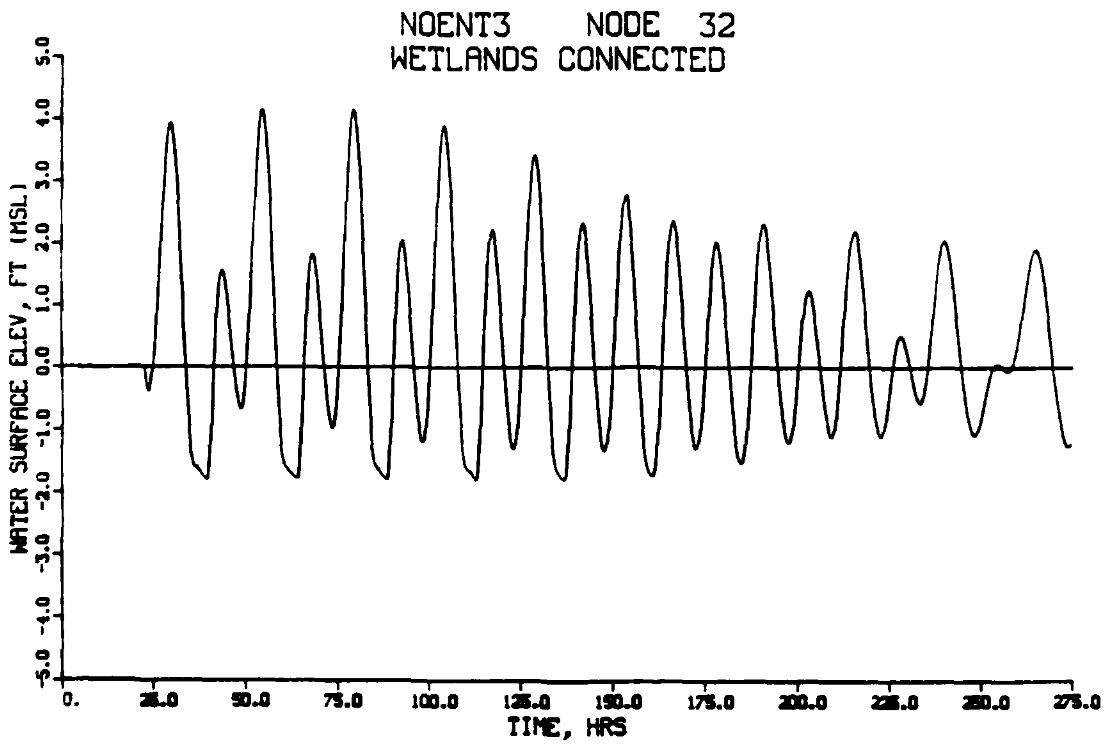


Figure K8. Tidal elevations in Outer Bolsa Bay under non-navigable entrance closed, no by-pass connector to marina conditions

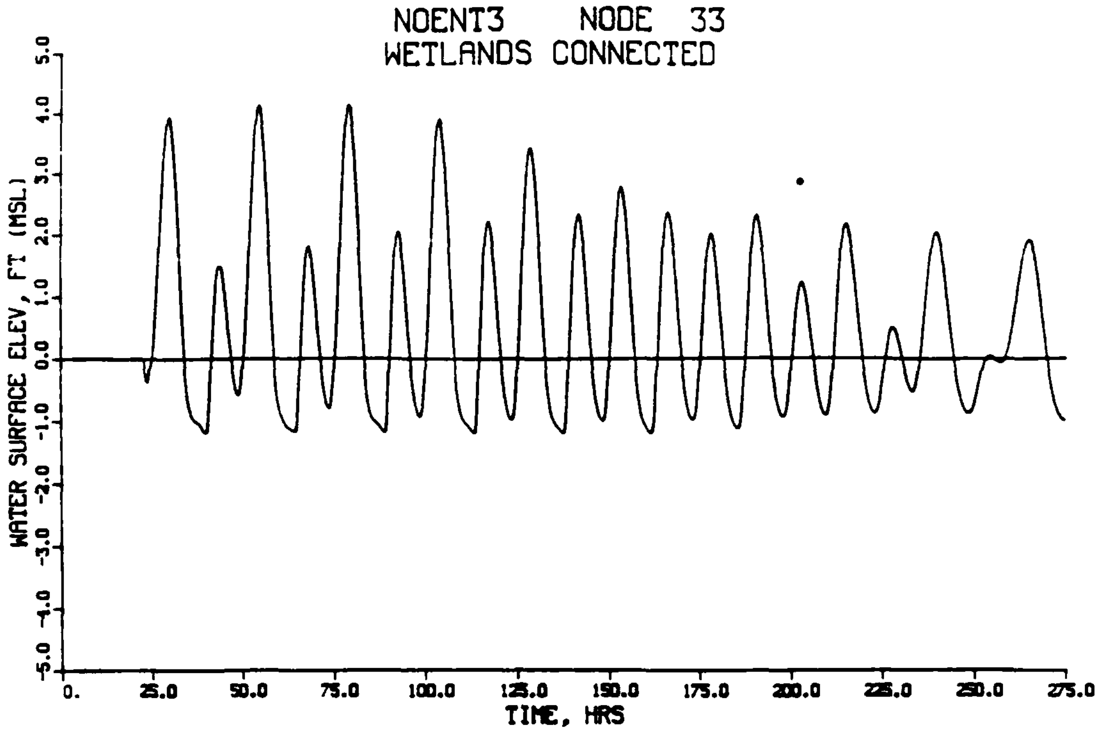


Figure K9. Tidal elevations in Outer Bolsa Bay under non-navigable entrance closed, no by-pass connector to marina conditions

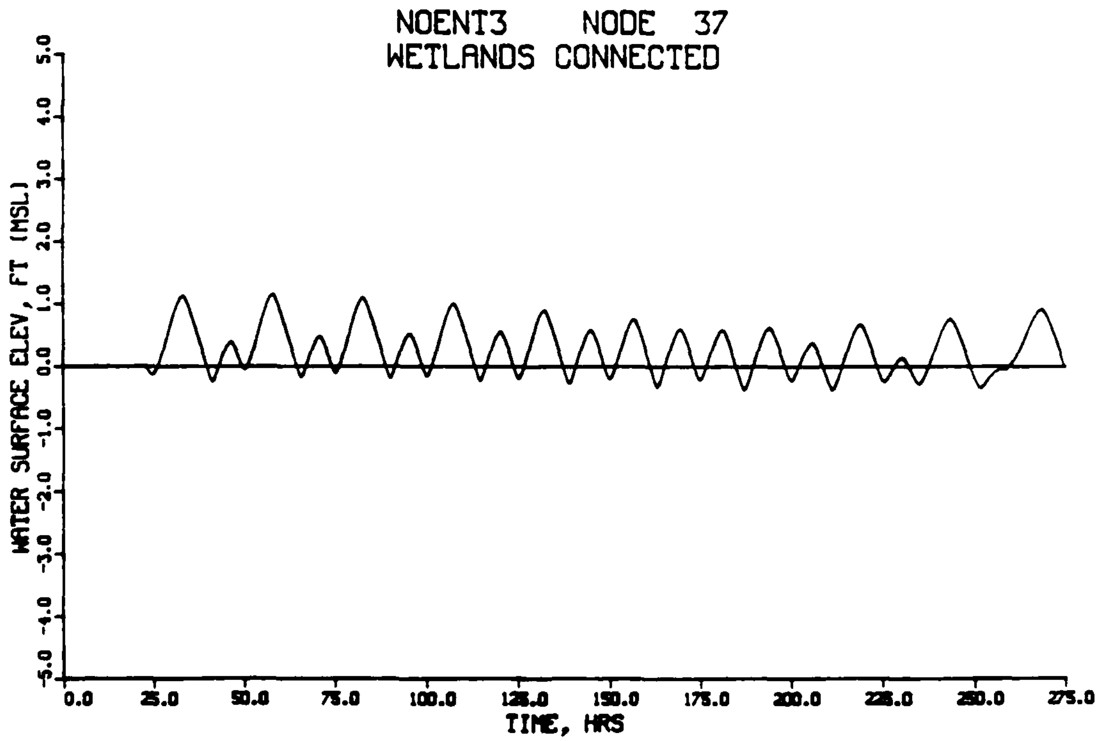


Figure K10. Tidal elevations in Inner Bolsa Bay under non-navigable entrance closed, no by-pass connector to marina conditions

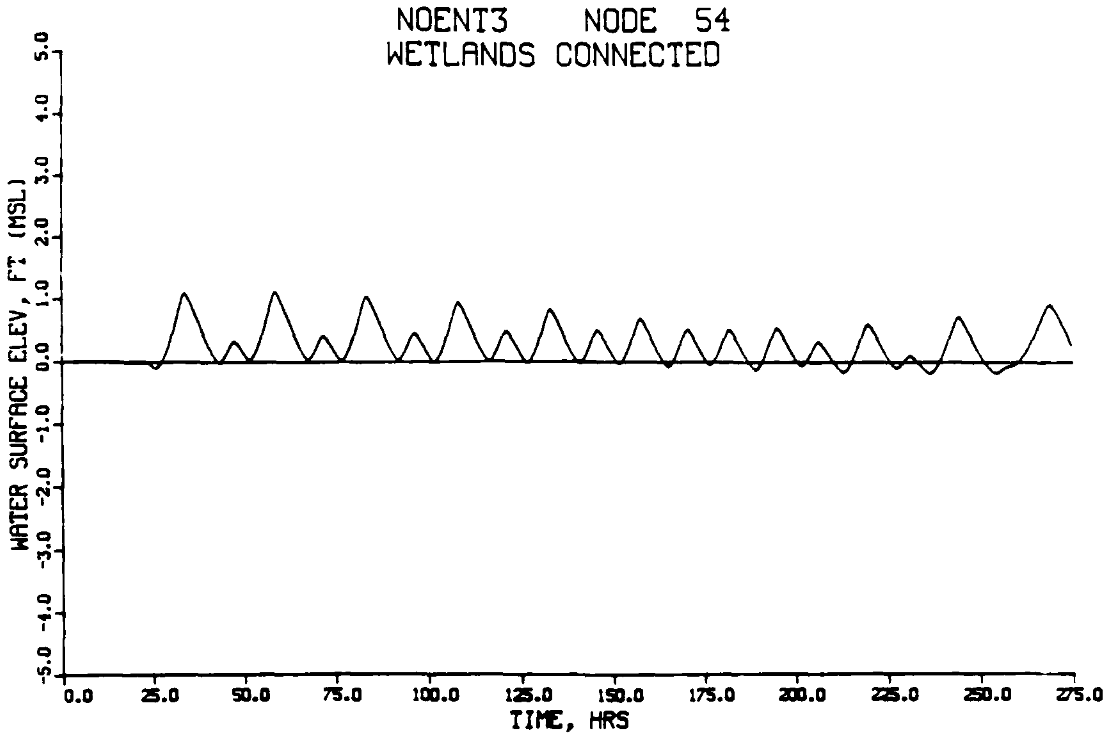


Figure K11. Tidal elevations in DFG muted tidal cell under non-navigable entrance closed, no by-pass connector to marina conditions

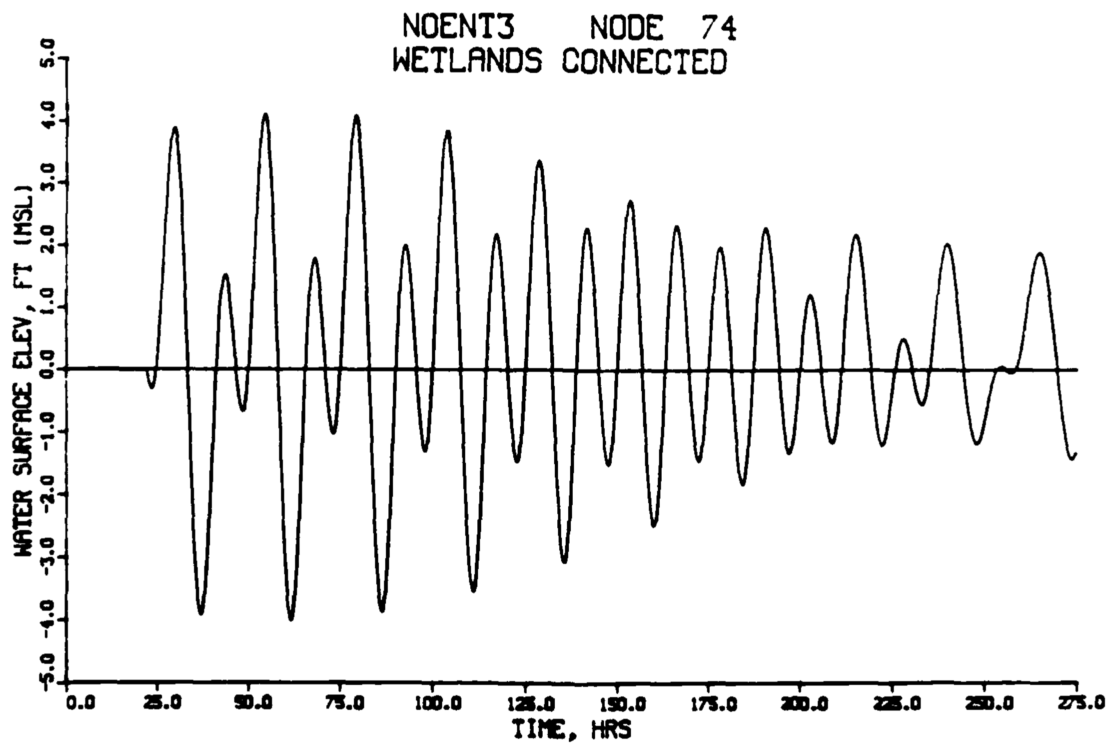


Figure K12. Tidal elevation in Pacific Ocean, driving non-navigable entrance closed, no by-pass connector to marina conditions

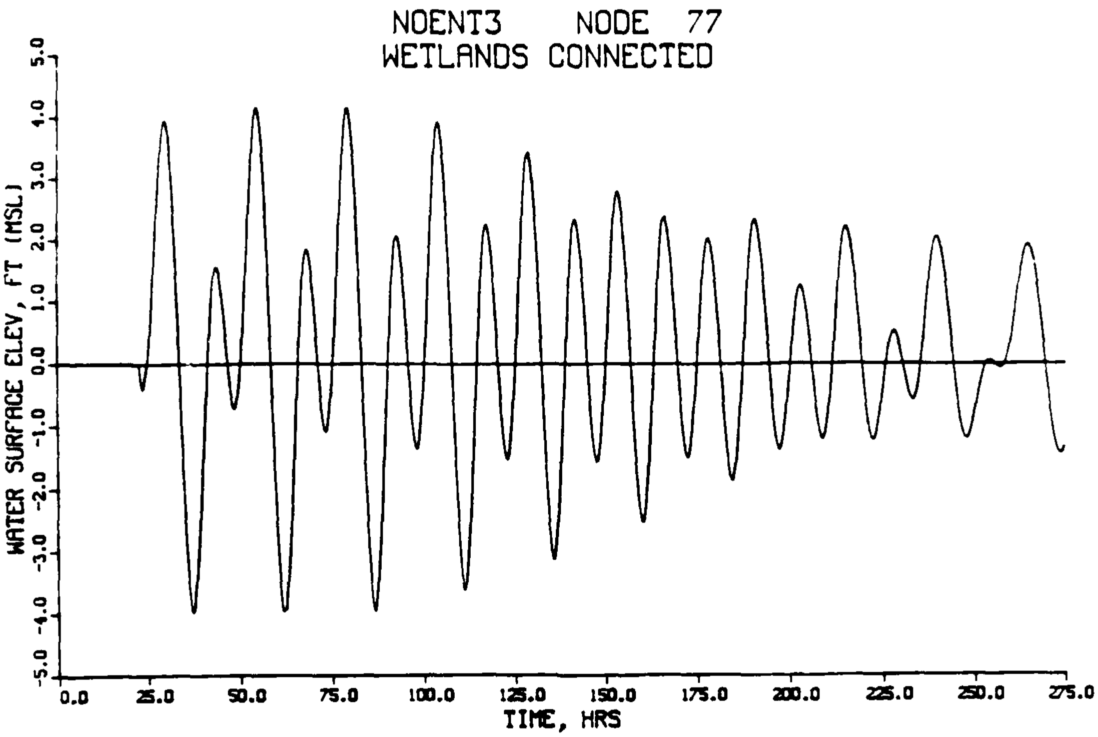


Figure K13. Tidal elevations in proposed marina under non-navigable entrance closed, no by-pass connector to marina conditions

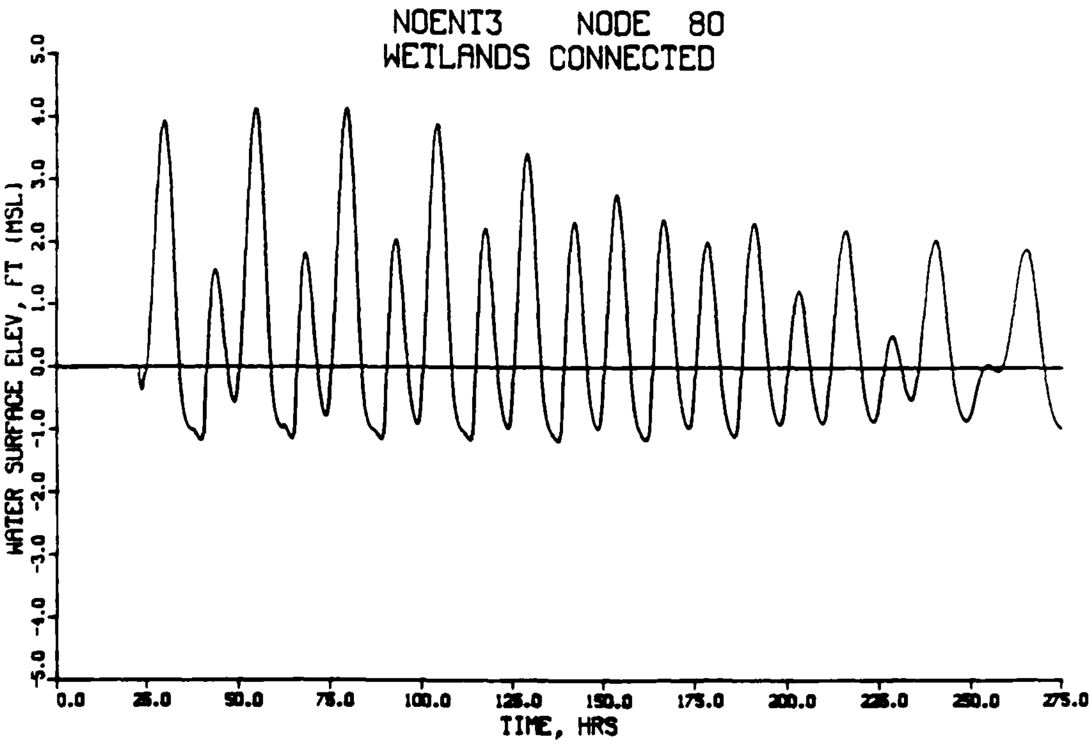


Figure K14. Tidal elevations in EGG-WFCC under non-navigable entrance closed, no by-pass connector to marina conditions

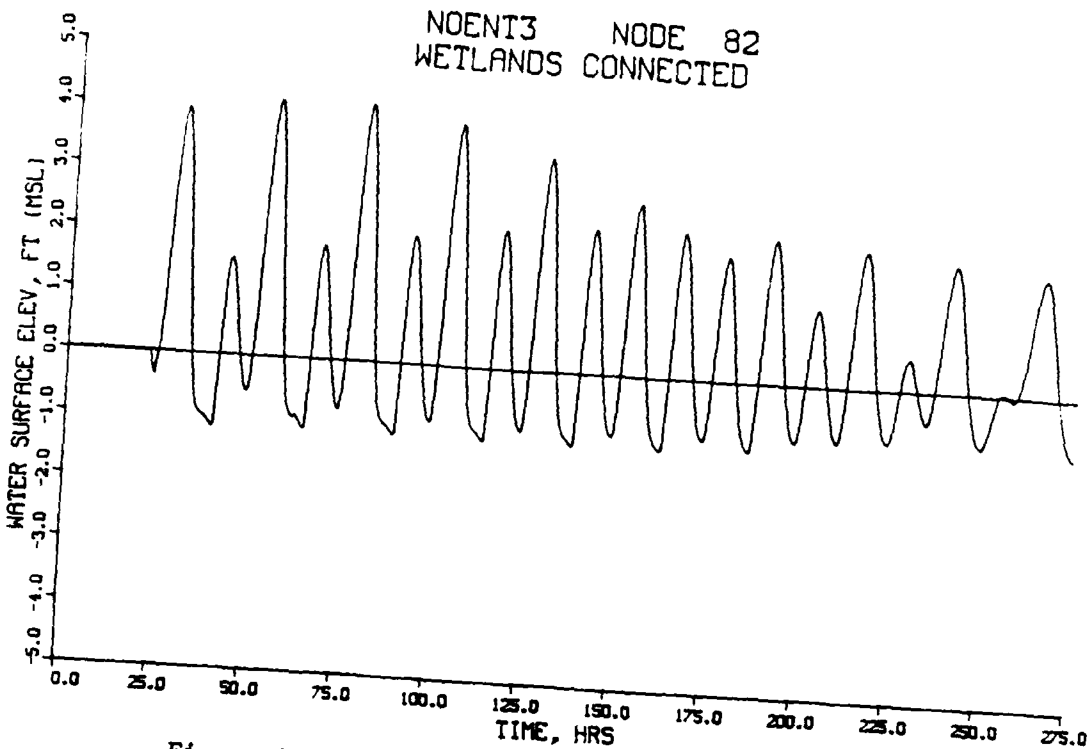


Figure K15. Tidal elevations in EGG-WFCC under non-navigable entrance closed, no by-pass connector to marina conditions

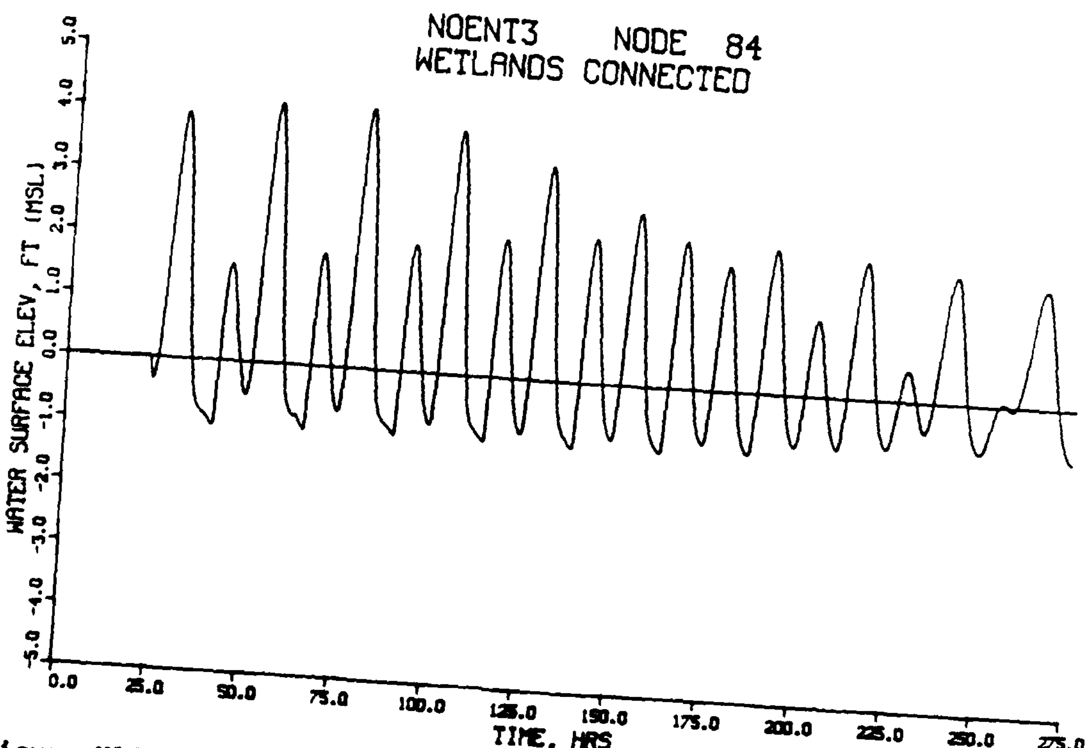


Figure K16. Tidal elevations in channel to proposed muted wetlands under non-navigable entrance closed, no by-pass connector to marina conditions

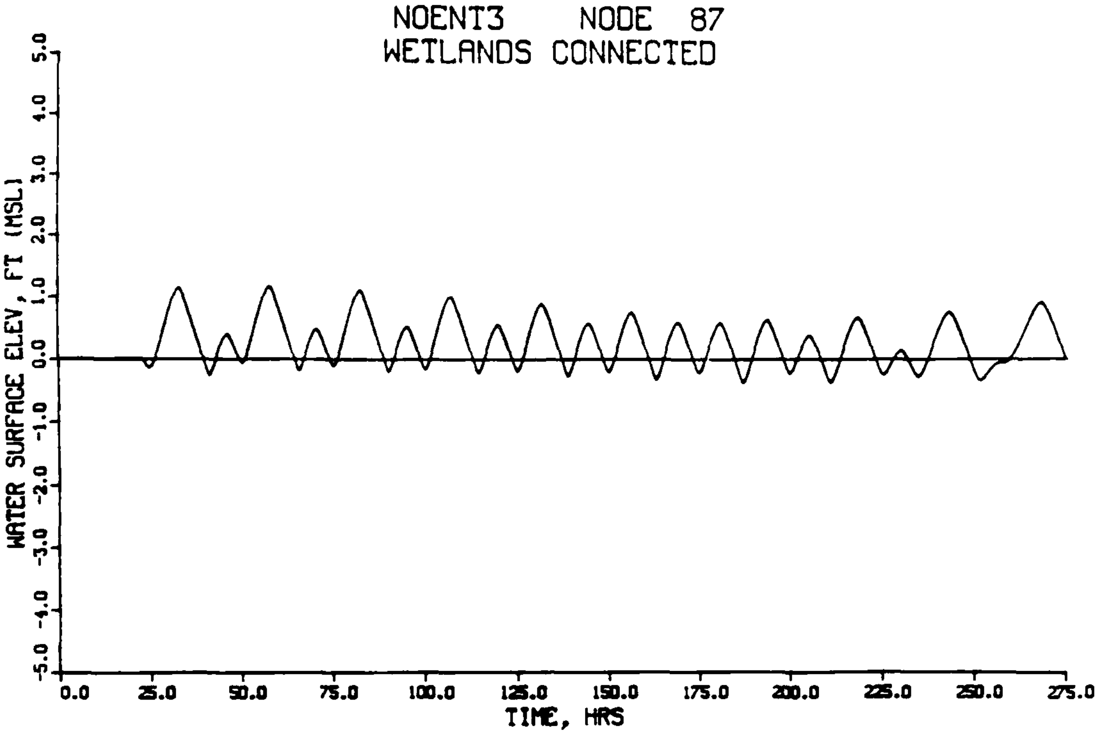


Figure K17. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance closed, no by-pass connector to marina conditions

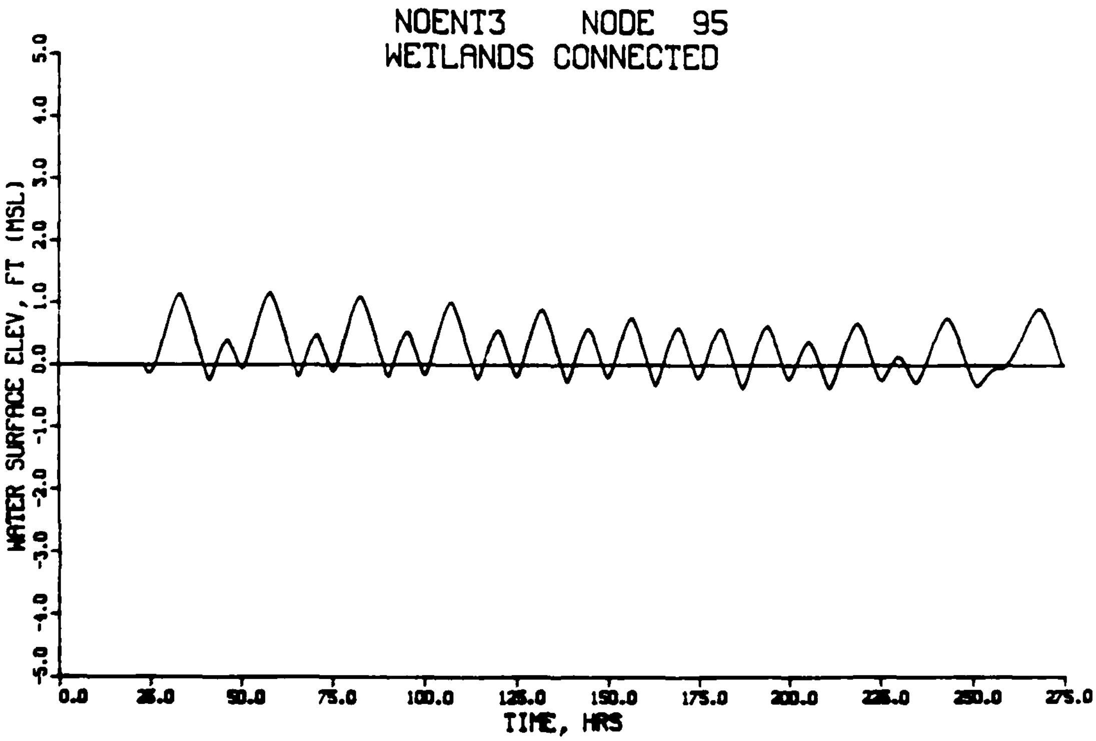


Figure K18. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance closed, no by-pass connector to marina conditions

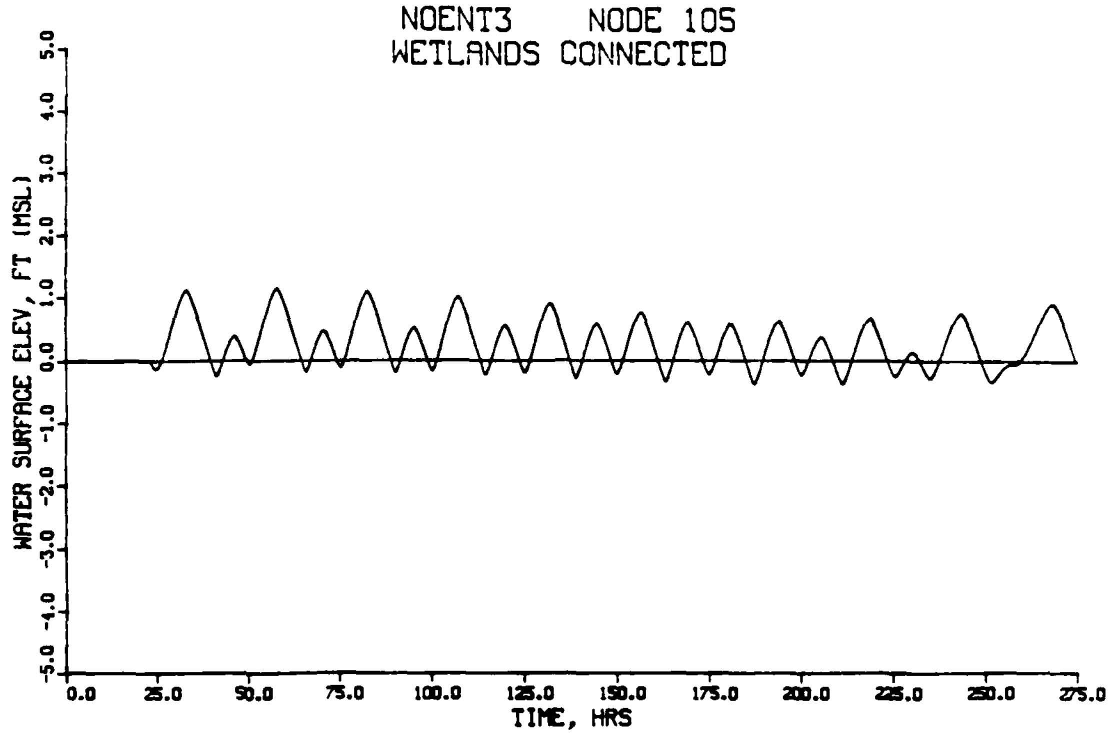


Figure K19. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance closed, no by-pass connector to marina conditions

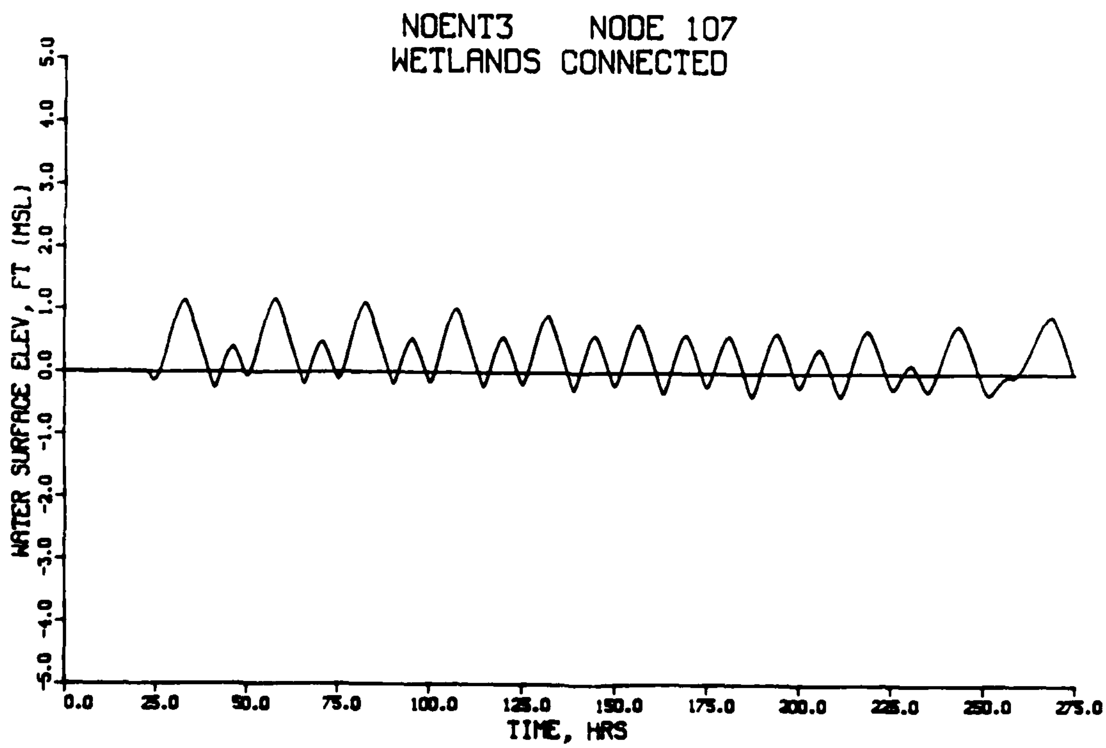


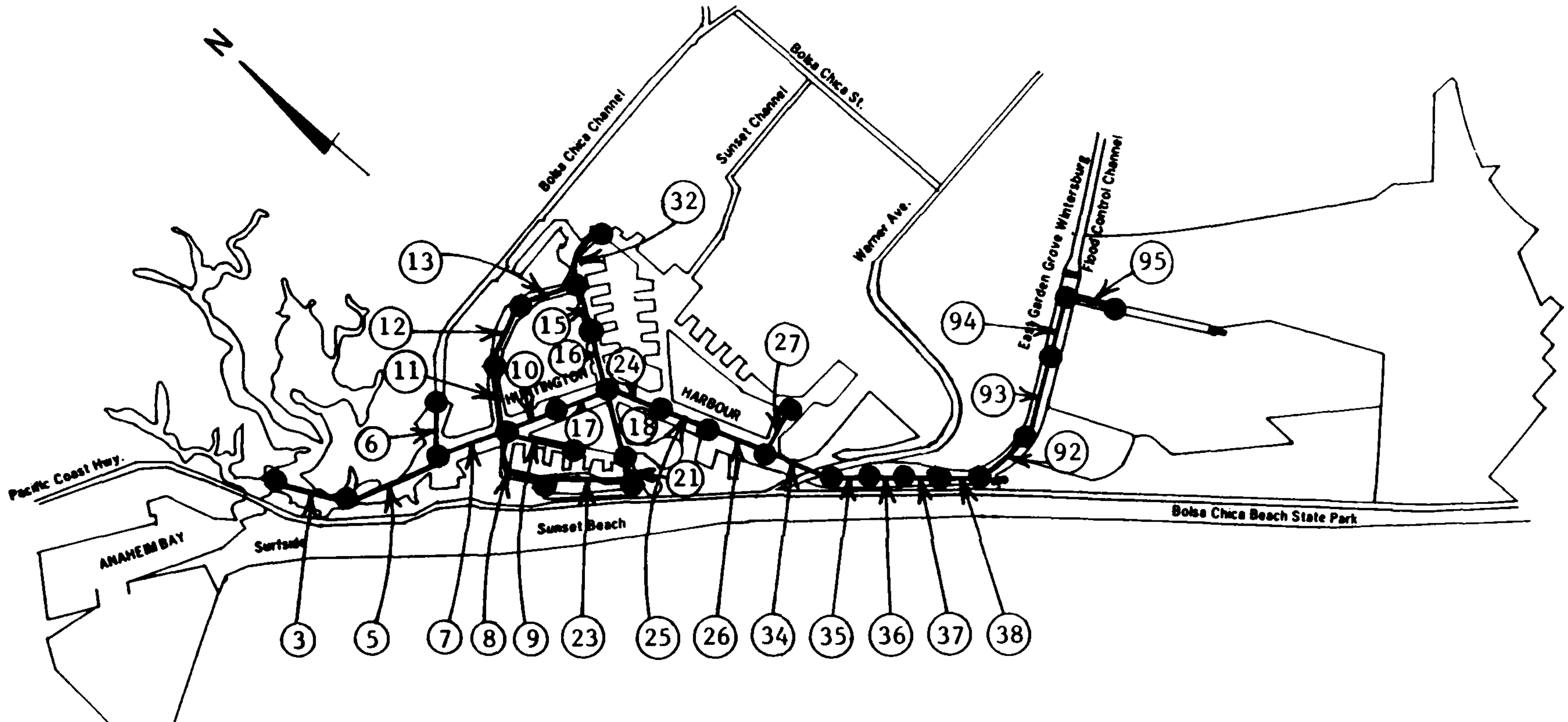
Figure K20. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance closed, no by-pass connector to marina conditions

APPENDIX L:

NOENT3

NON-NAVIGABLE ENTRANCE CHANNEL CLOSED
AND
NO BY-PASS CONNECTOR CHANNEL TO MARINA

AVERAGE CHANNEL VELOCITIES



BOLSA BAY, CALIFORNIA

NOENT3
Location of links for displaying average channel velocities
under non-navigable entrance channel closed and no by-pass connector channel to marina conditions

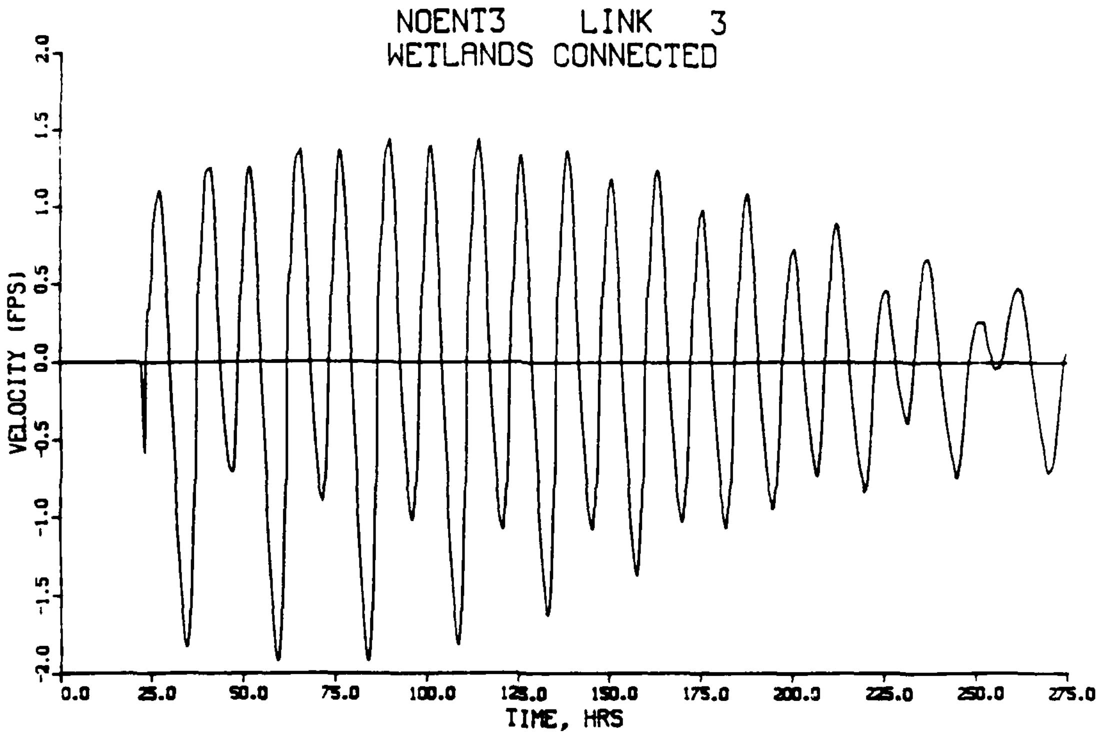


Figure L1. Average channel velocities in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

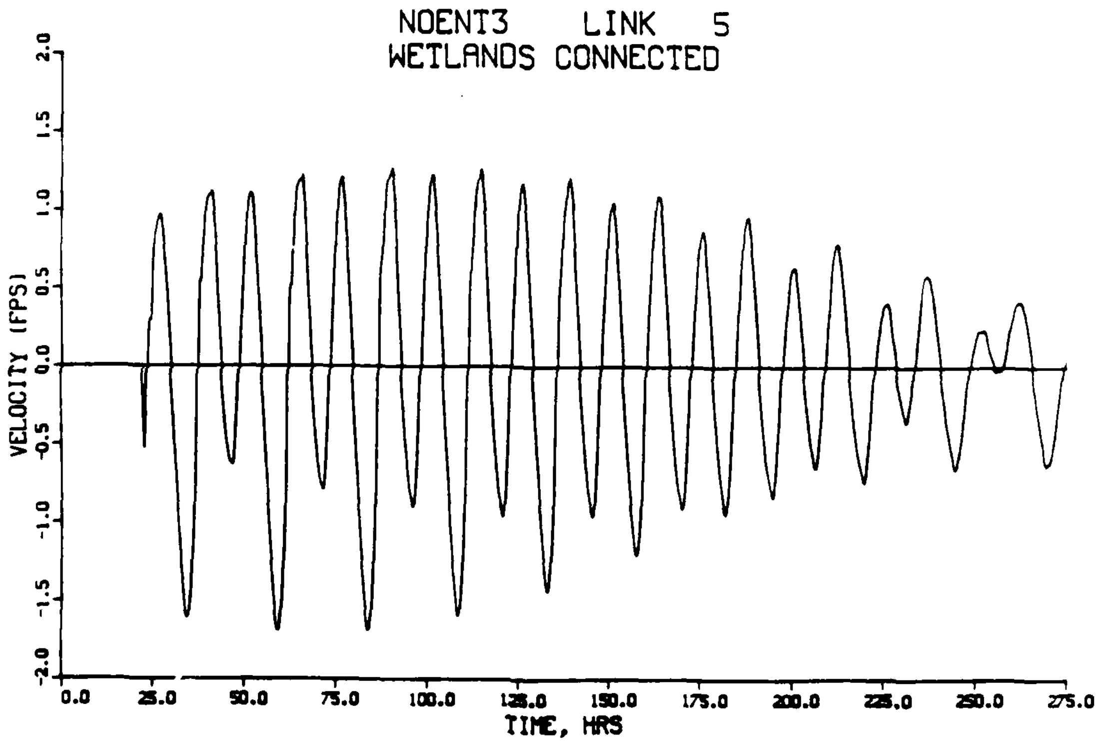


Figure L2. Average channel velocities in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

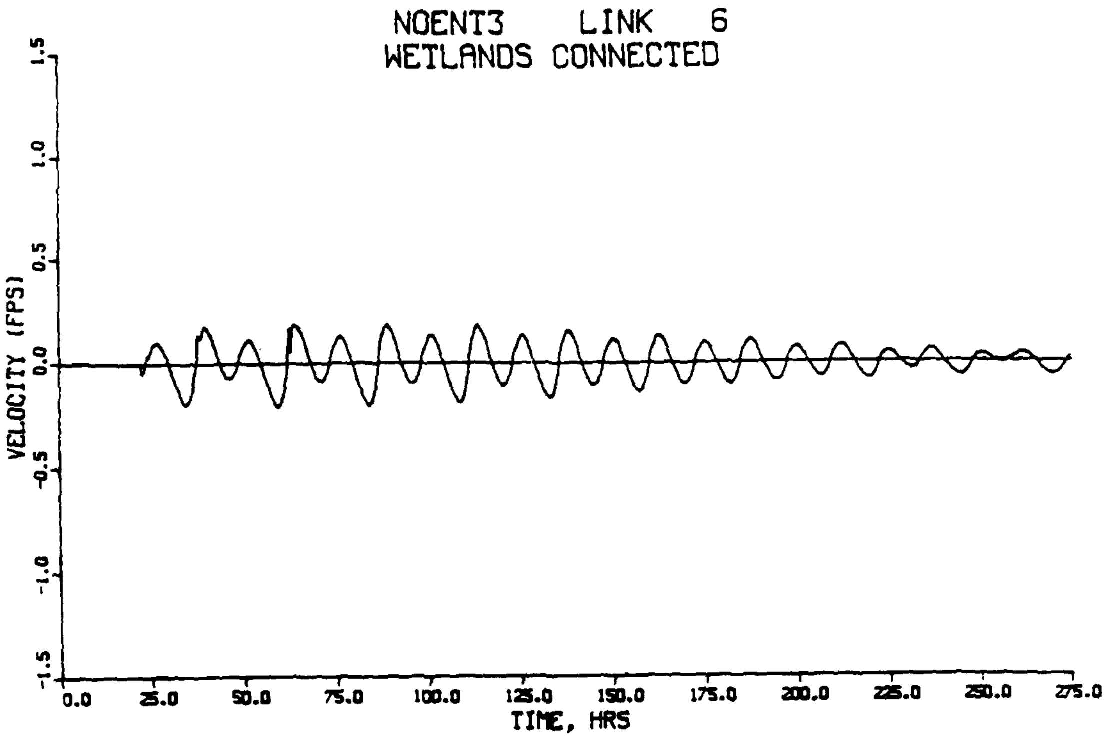


Figure L3. Average channel velocities in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

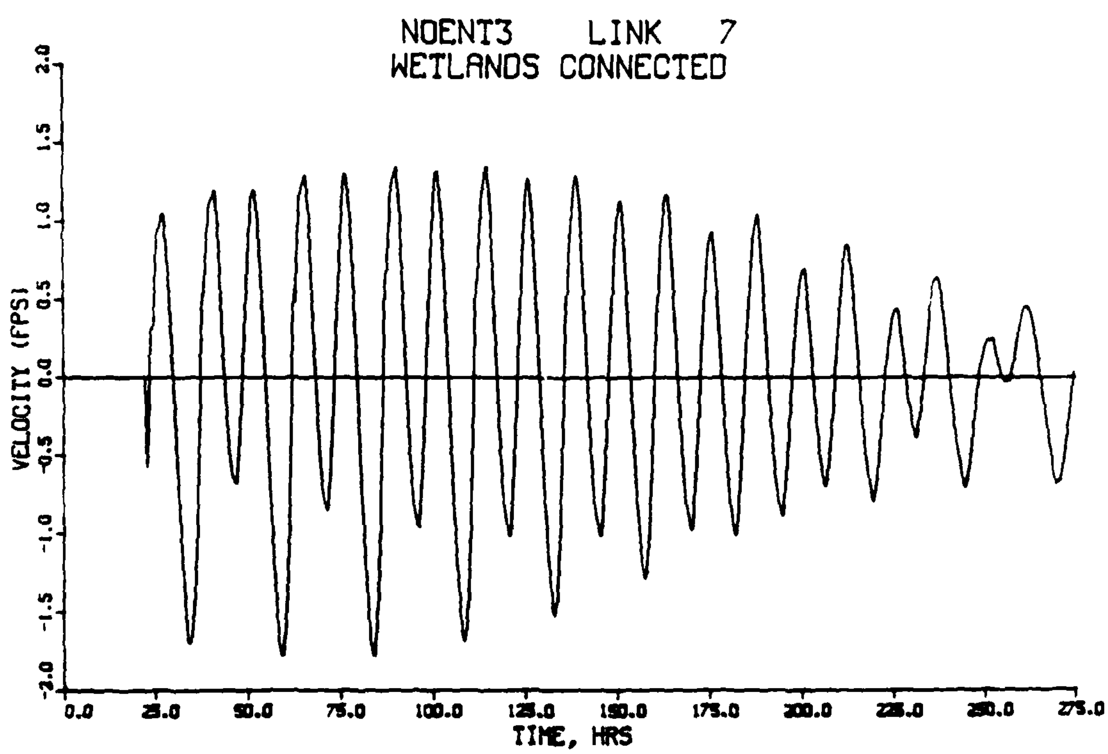


Figure L4. Average channel velocities in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

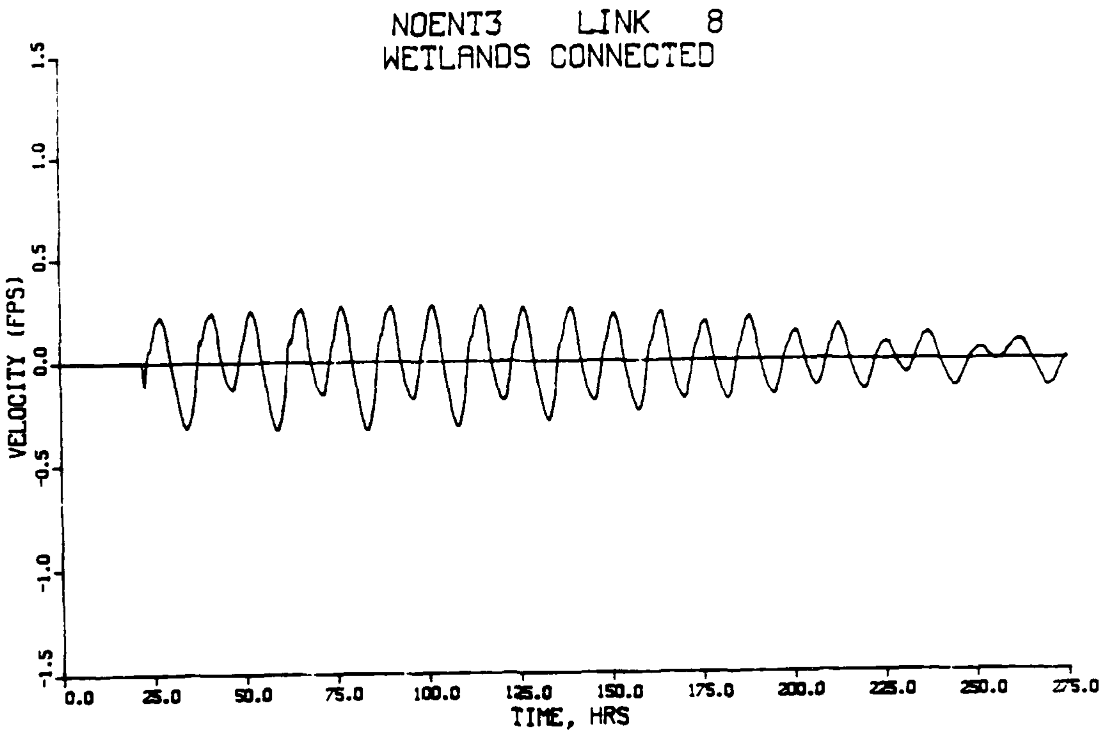


Figure L5. Average channel velocities in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

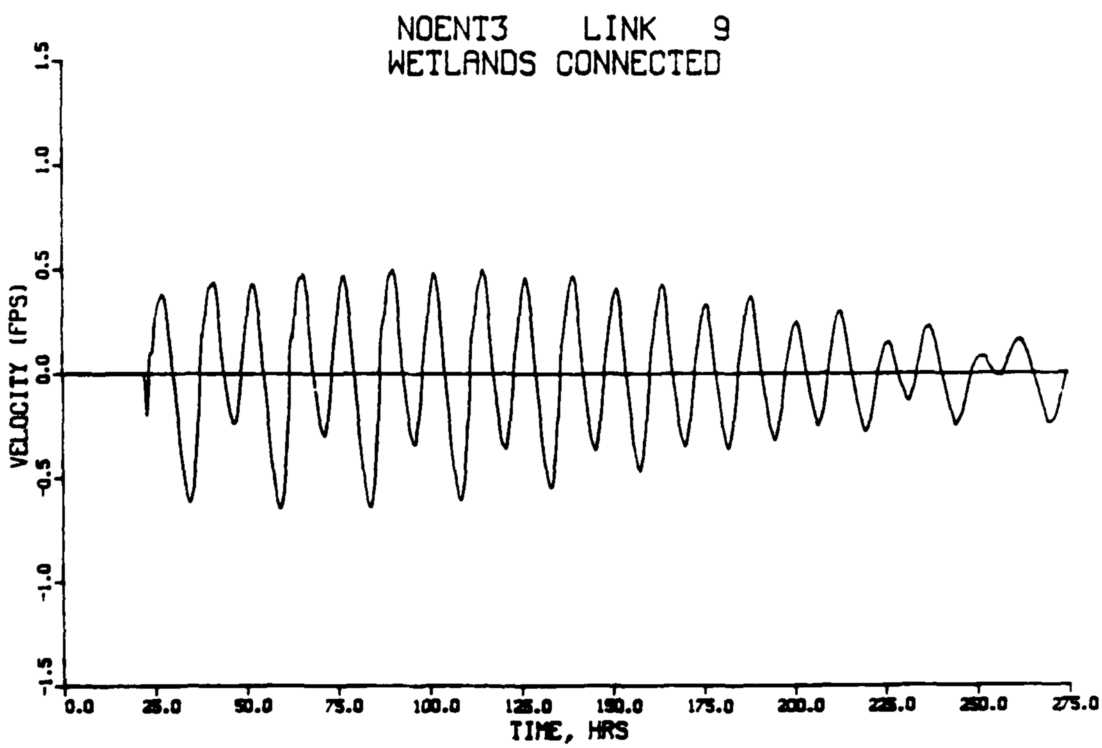


Figure L6. Average channel velocities in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

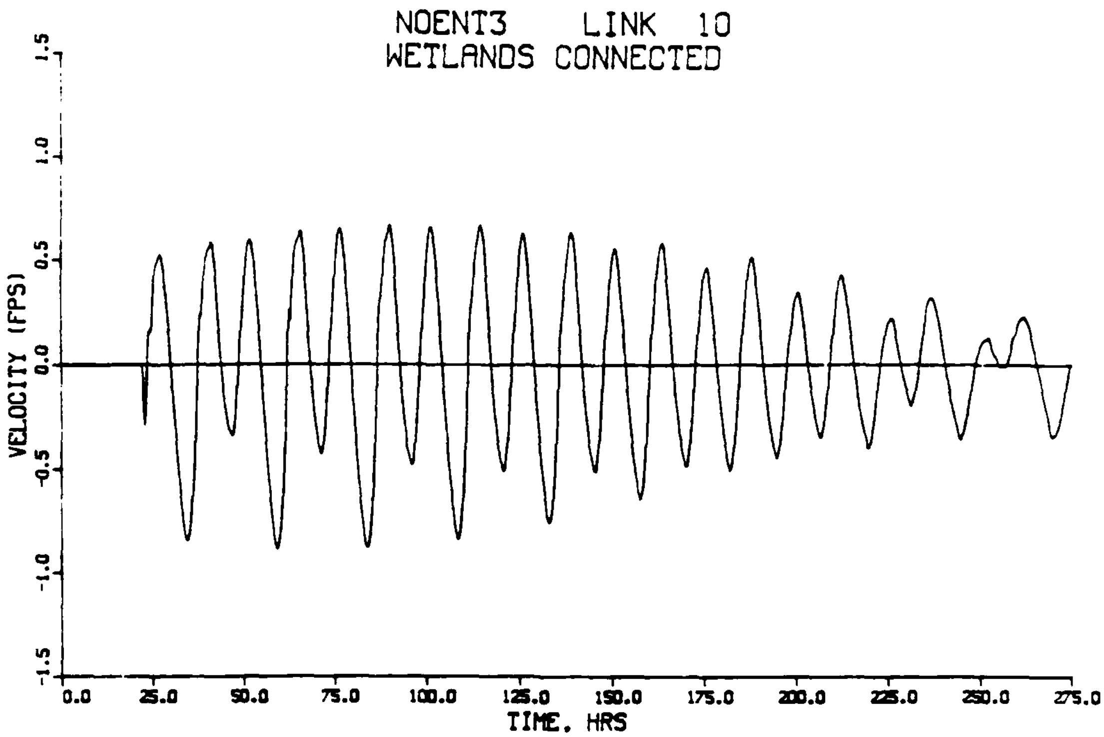


Figure L7. Average channel velocities in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

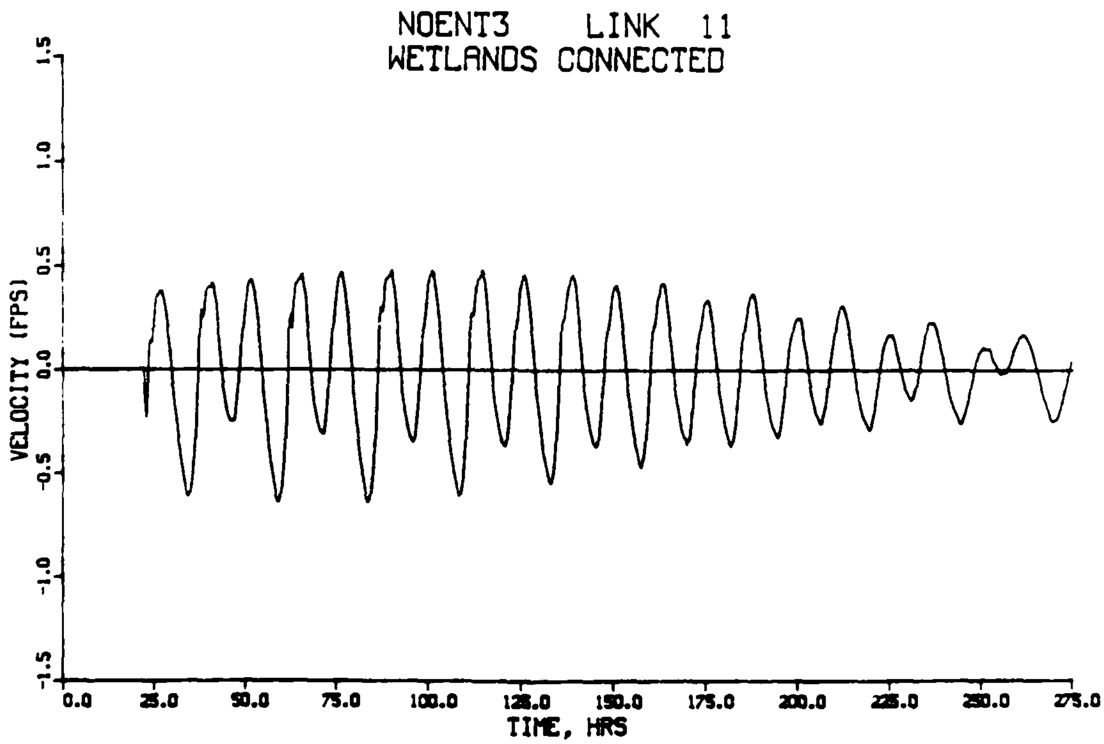


Figure L8. Average channel velocities in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

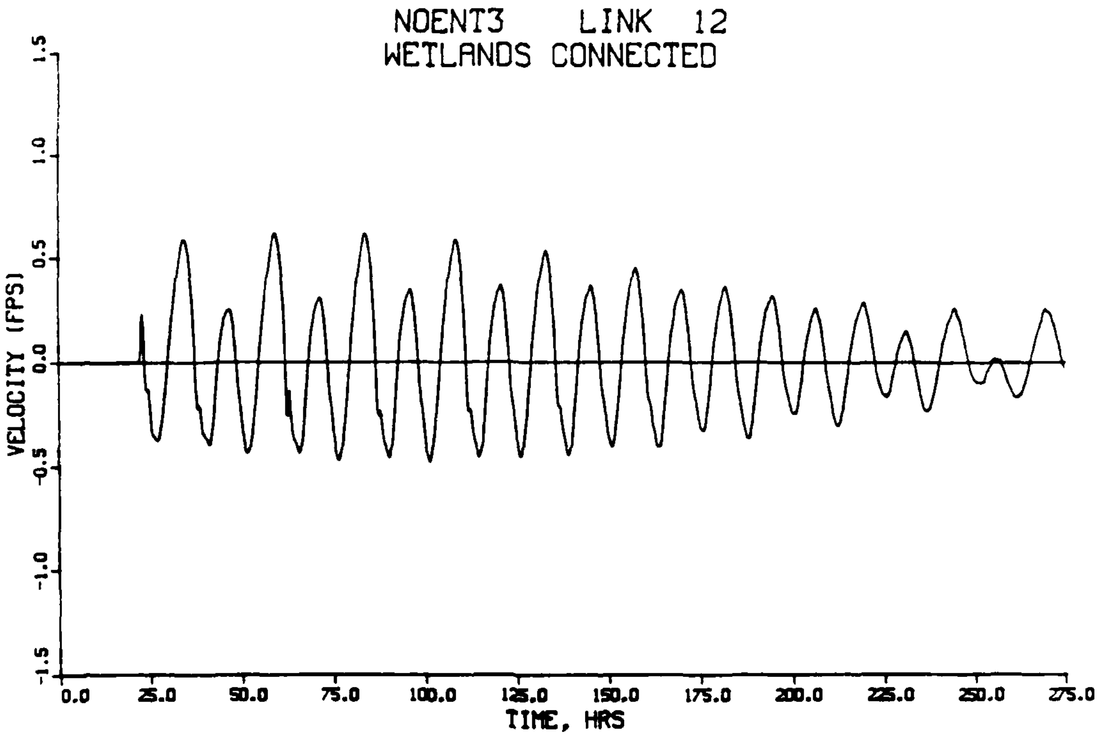


Figure L9. Average channel velocities in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

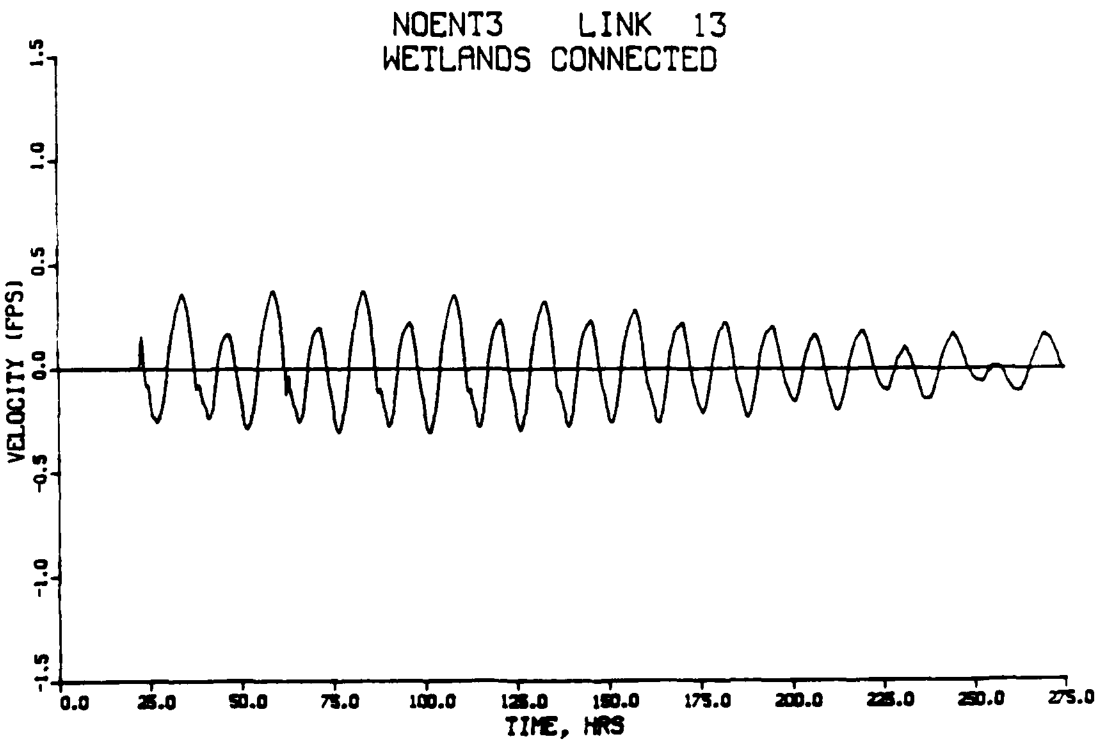


Figure L10. Average channel velocities in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

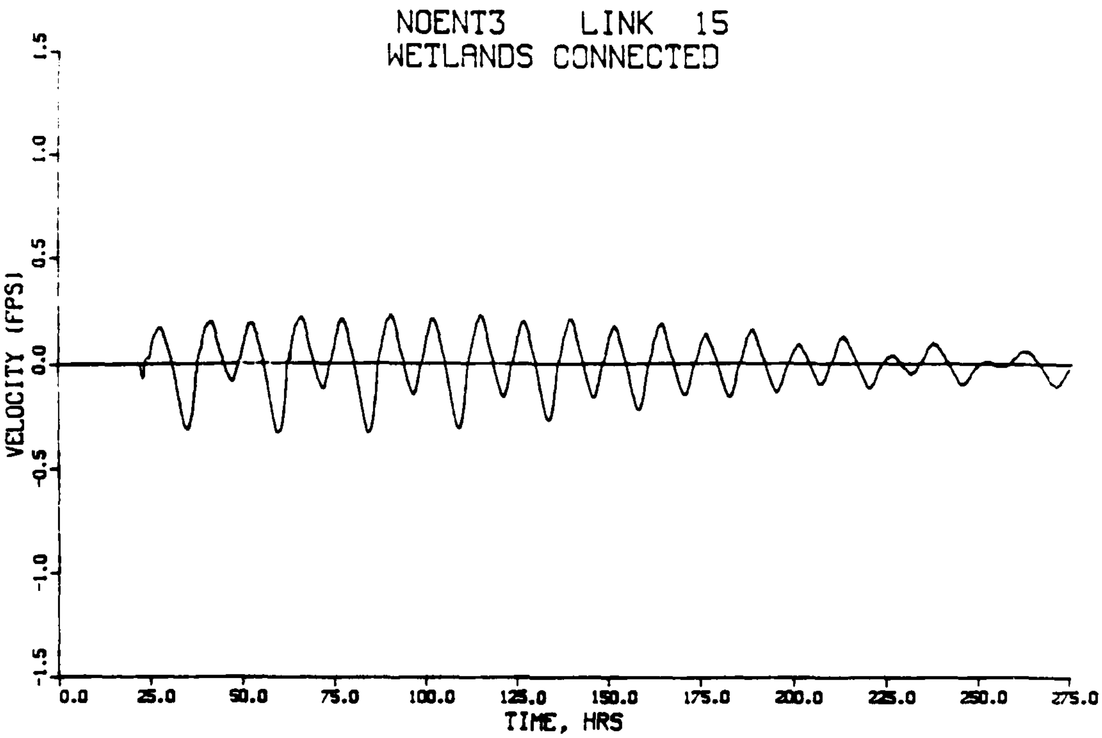


Figure L11. Average channel velocities in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

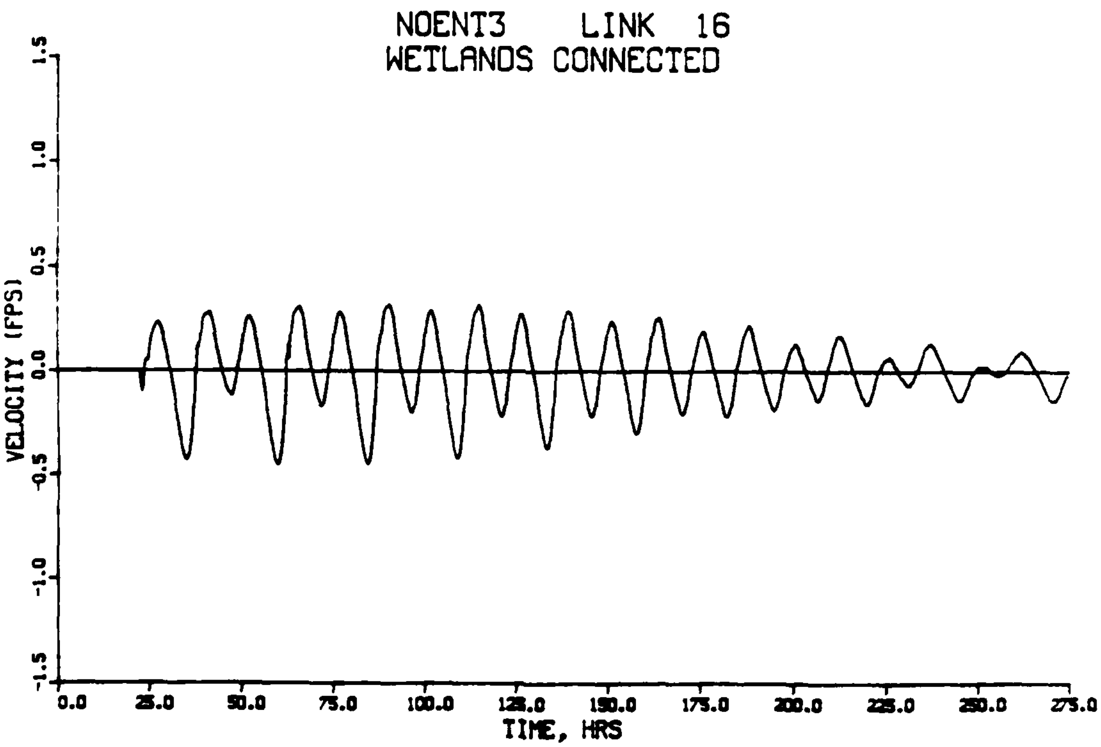


Figure L12. Average channel velocities in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

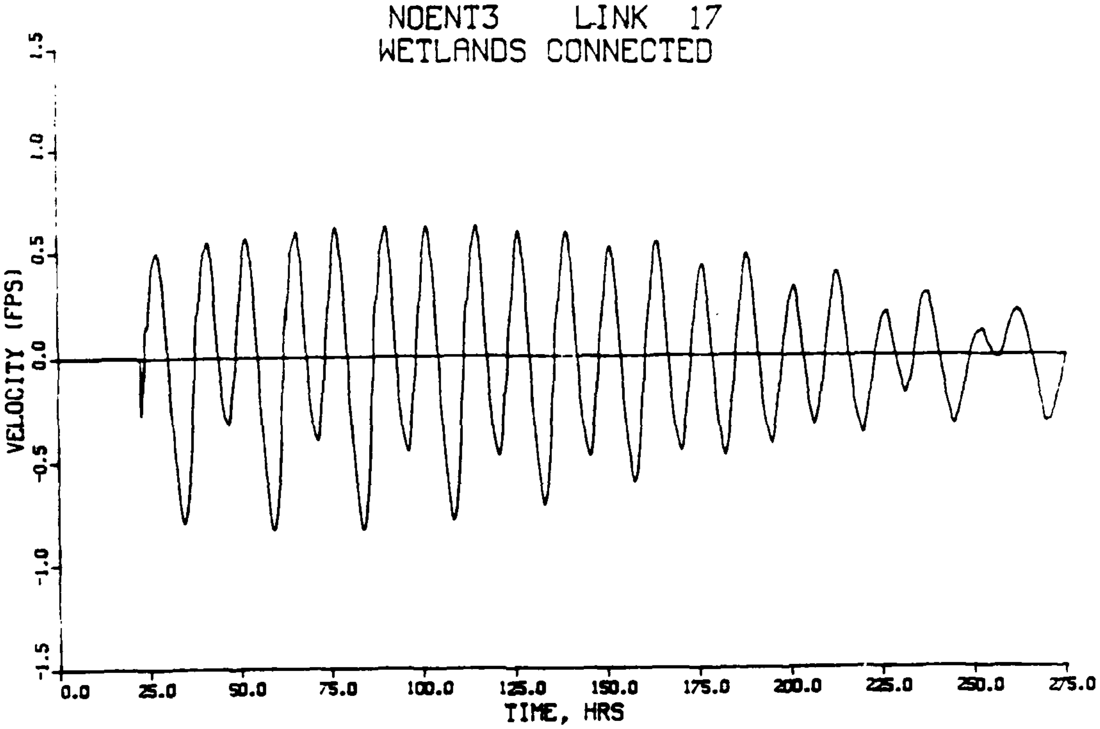


Figure L13. Average channel velocities in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

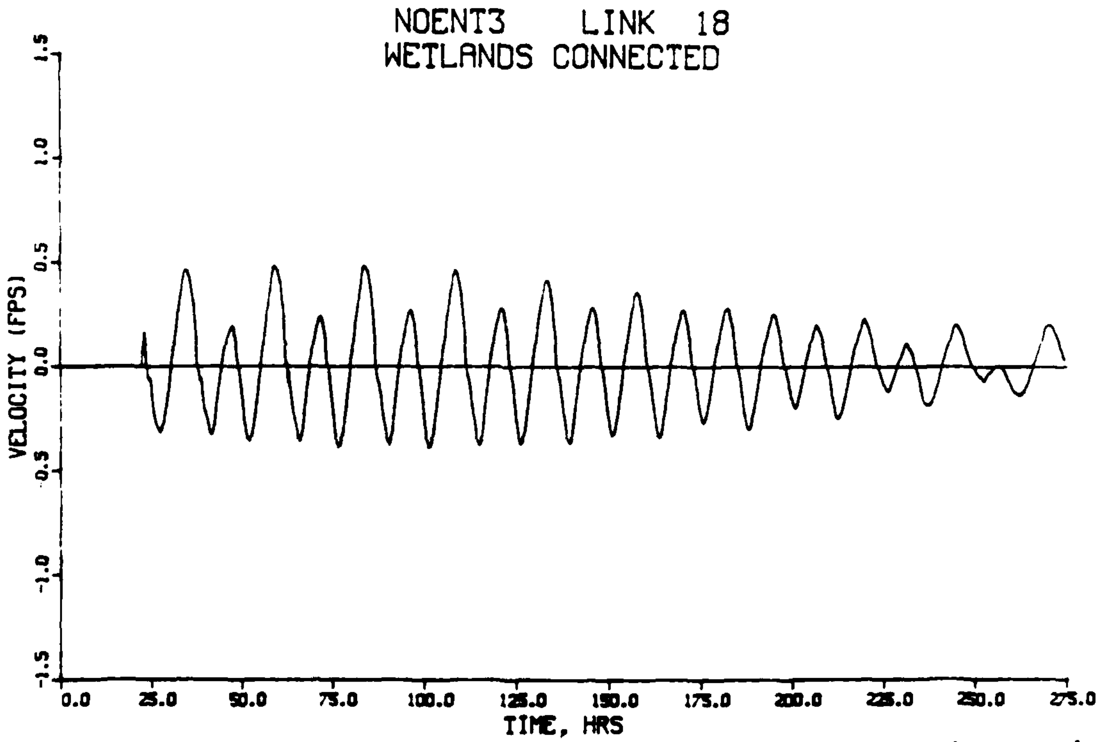


Figure L14. Average channel velocities in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

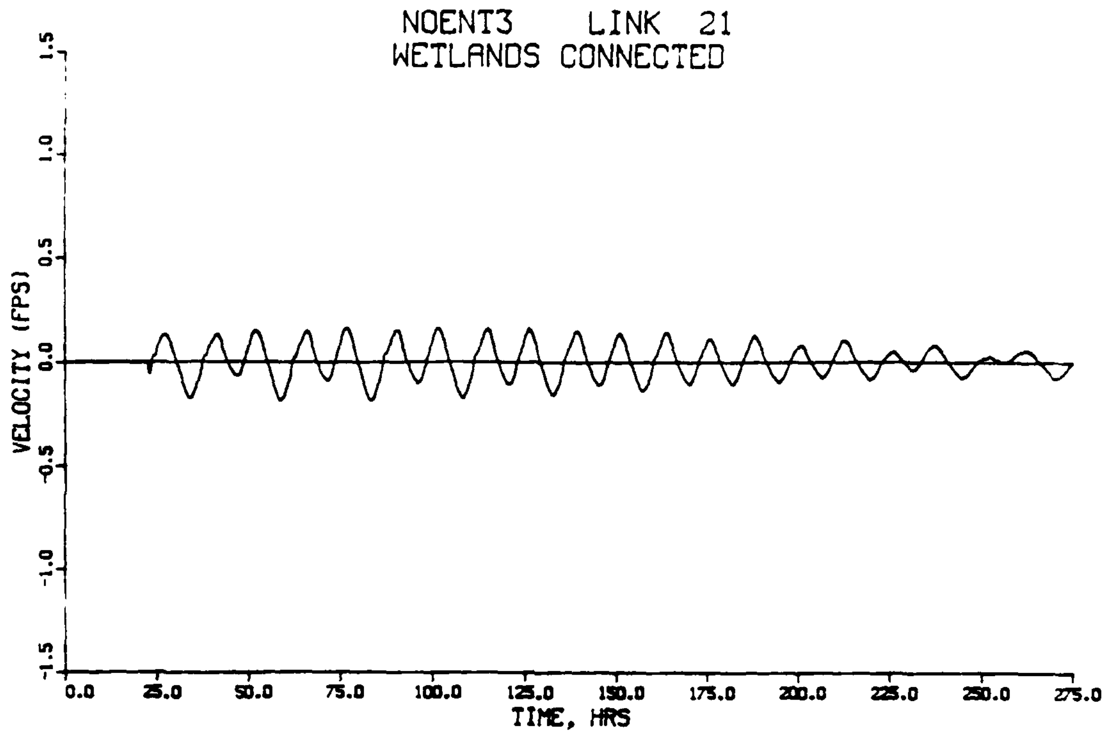


Figure L15. Average channel velocities in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

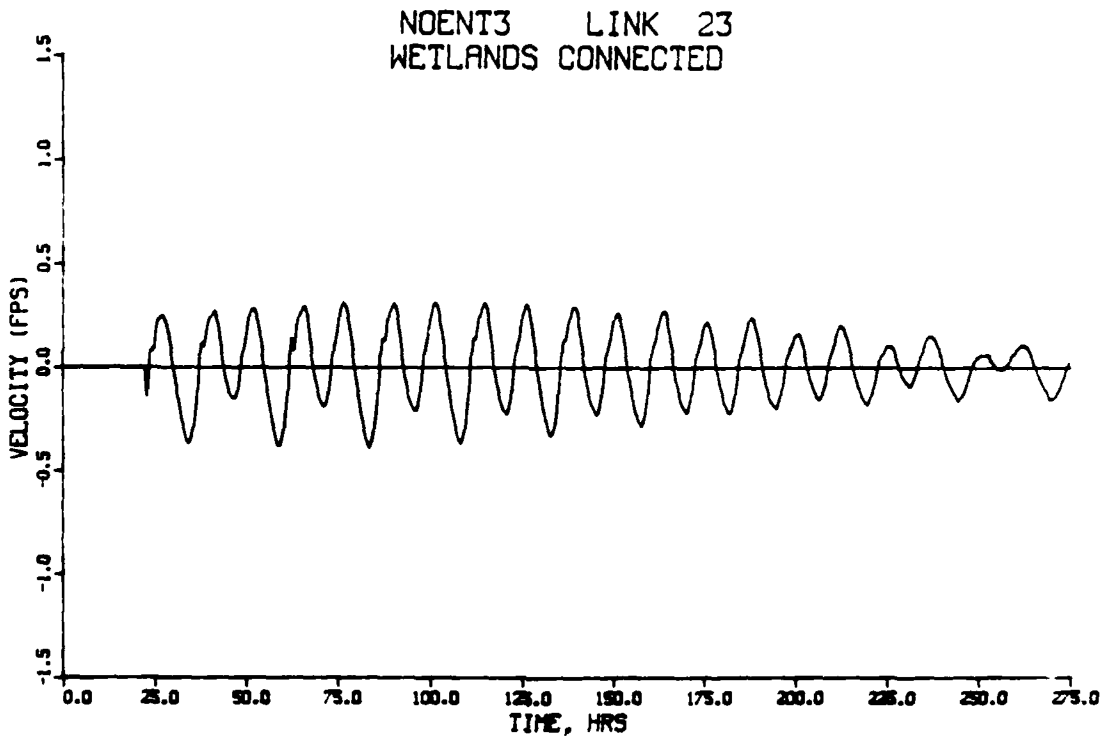


Figure L16. Average channel velocities in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

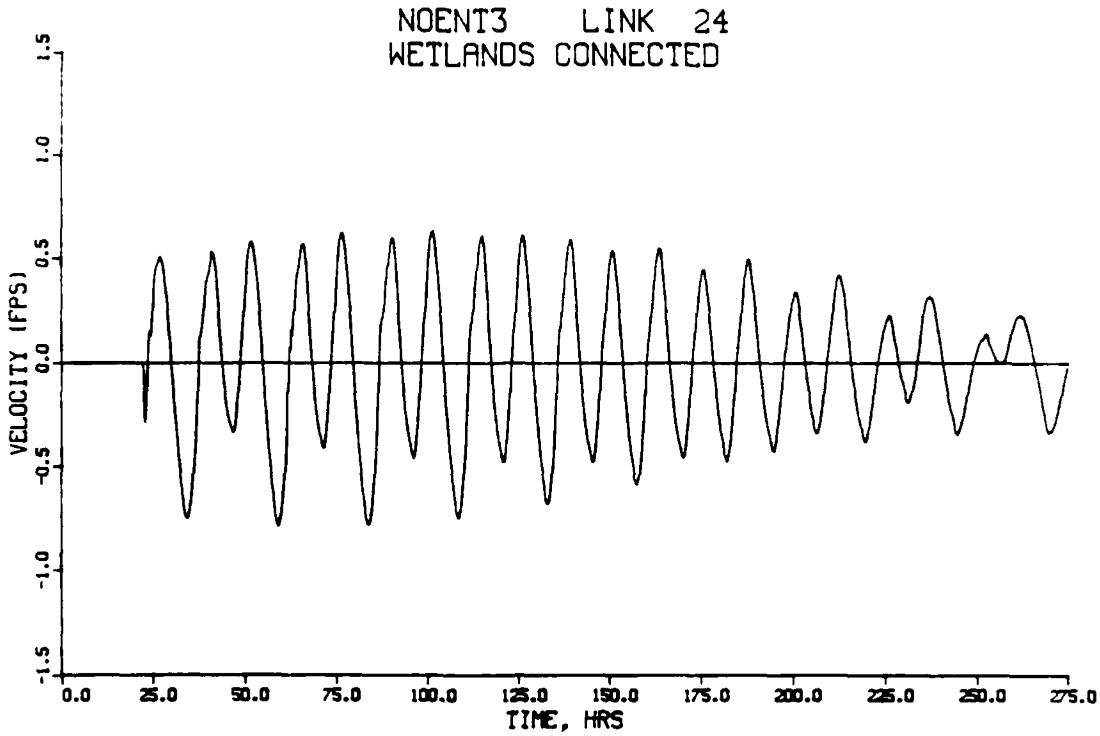


Figure L17. Average channel velocities in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

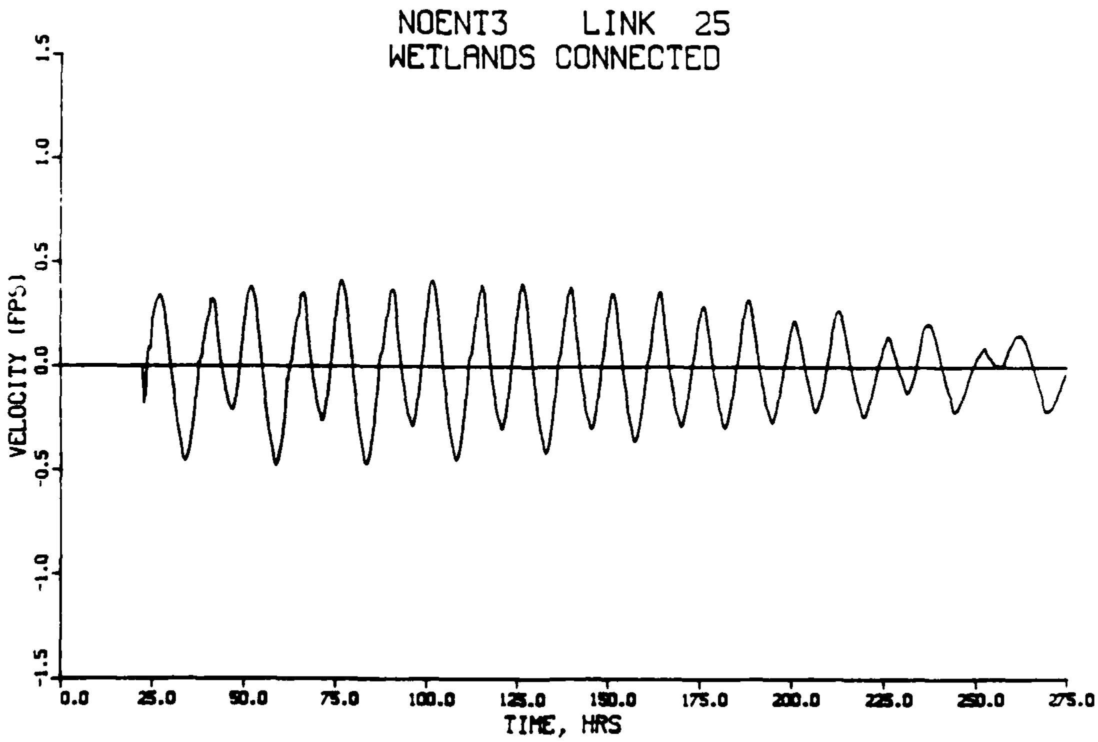


Figure L18. Average channel velocities in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

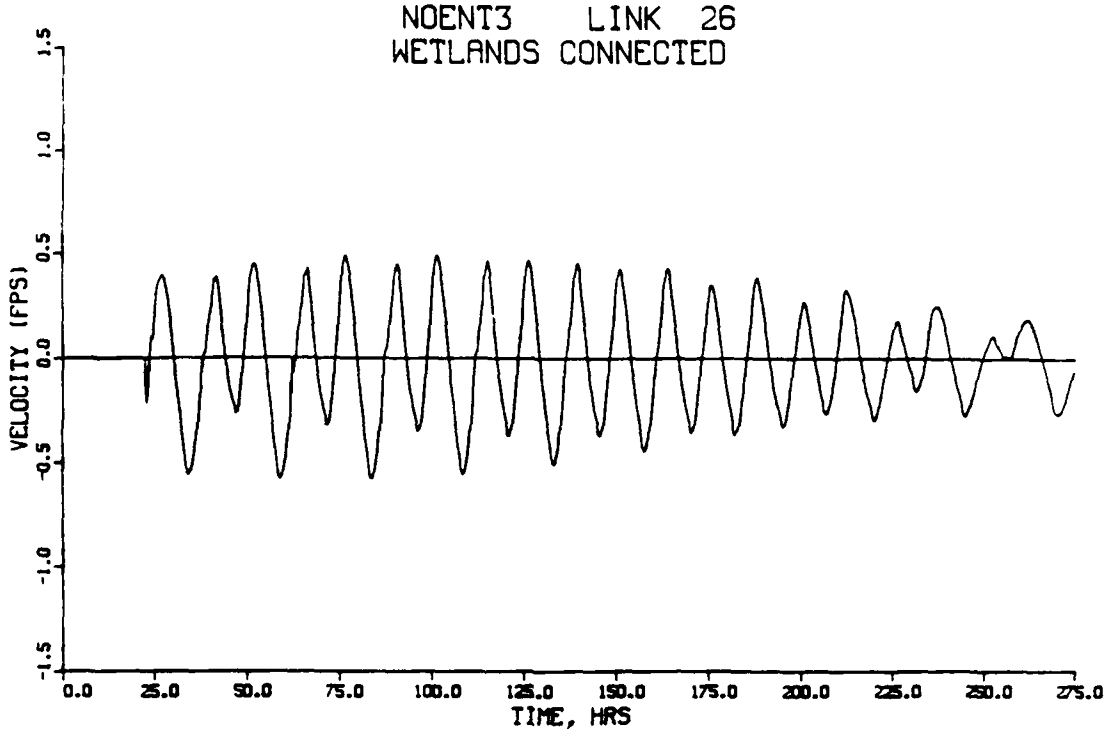


Figure L19. Average channel velocities in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

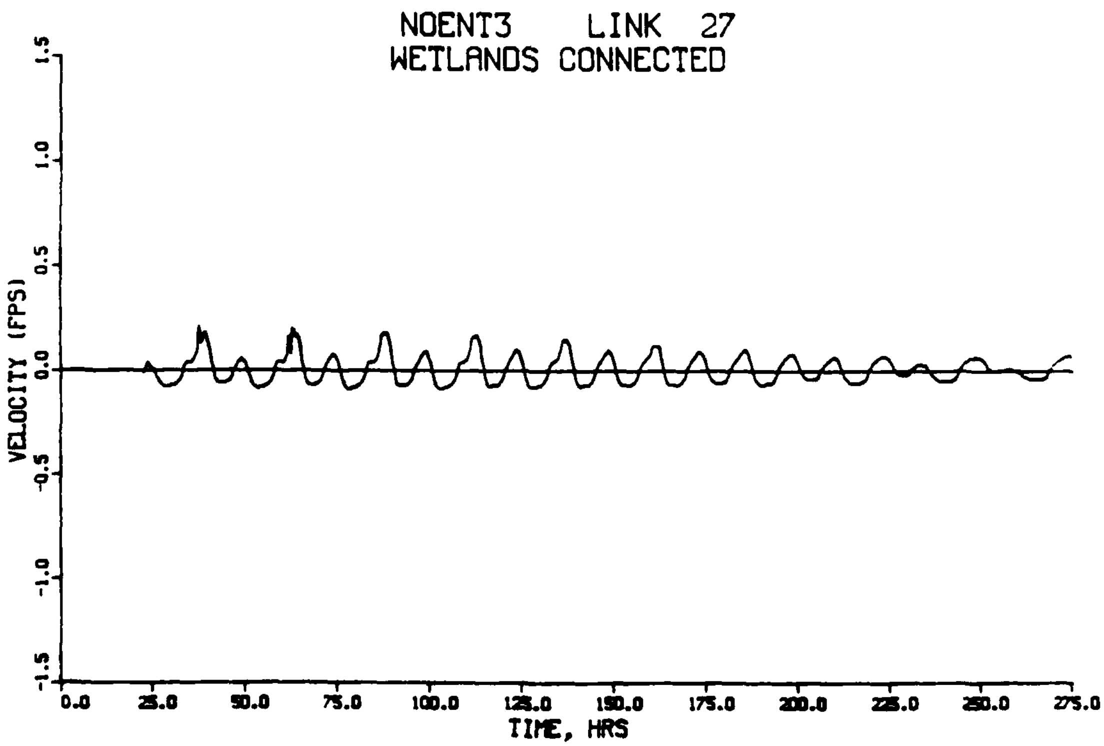


Figure L20. Average channel velocities in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

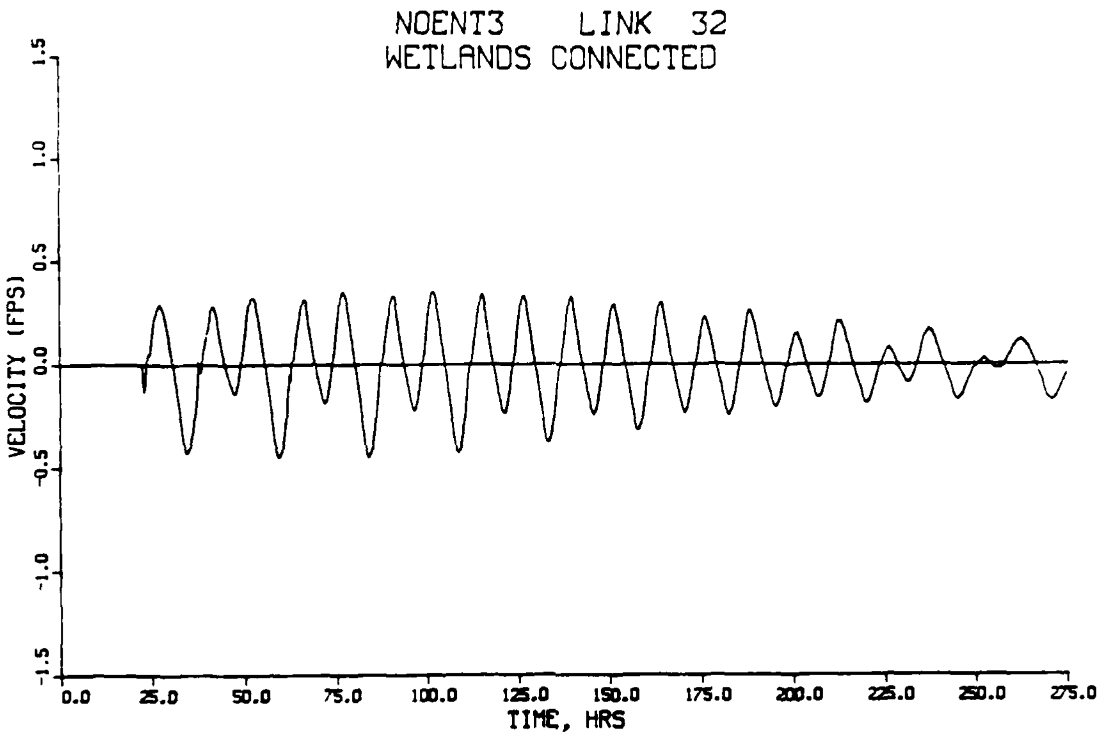


Figure L21. Average channel velocities in Huntington Harbour under non-navigable entrance closed, no by-pass connector to marina conditions

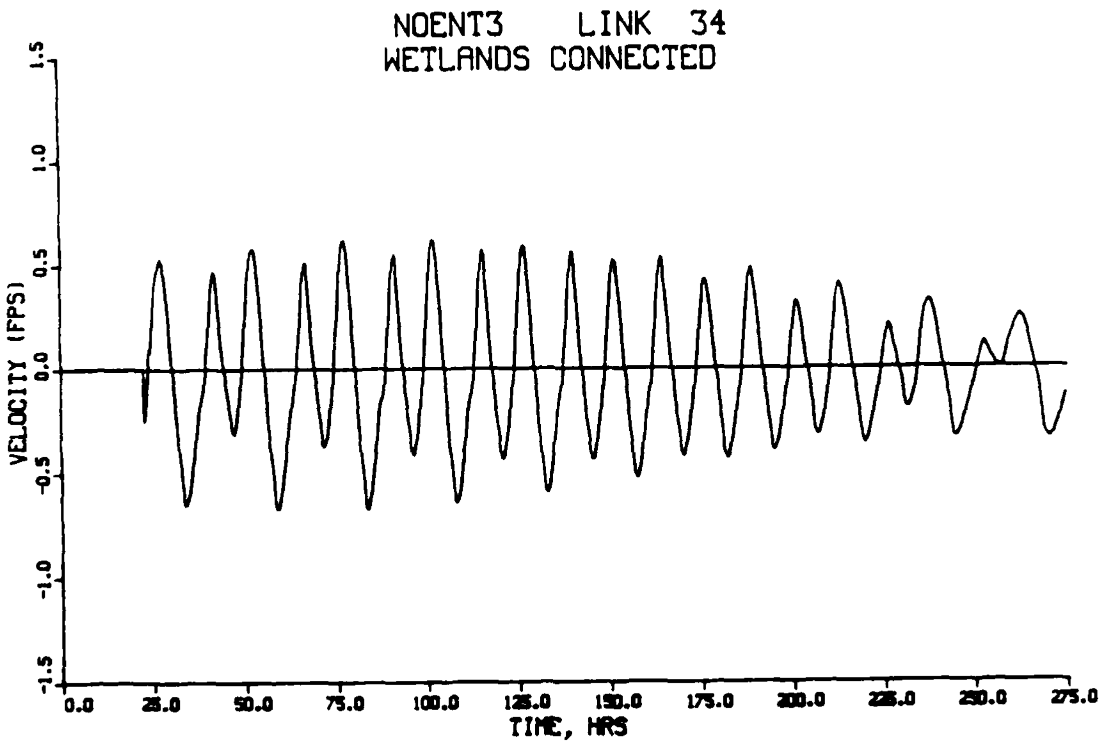


Figure L22. Average channel velocities at previous Warner Avenue under non-navigable entrance closed, no by-pass connector to marina conditions

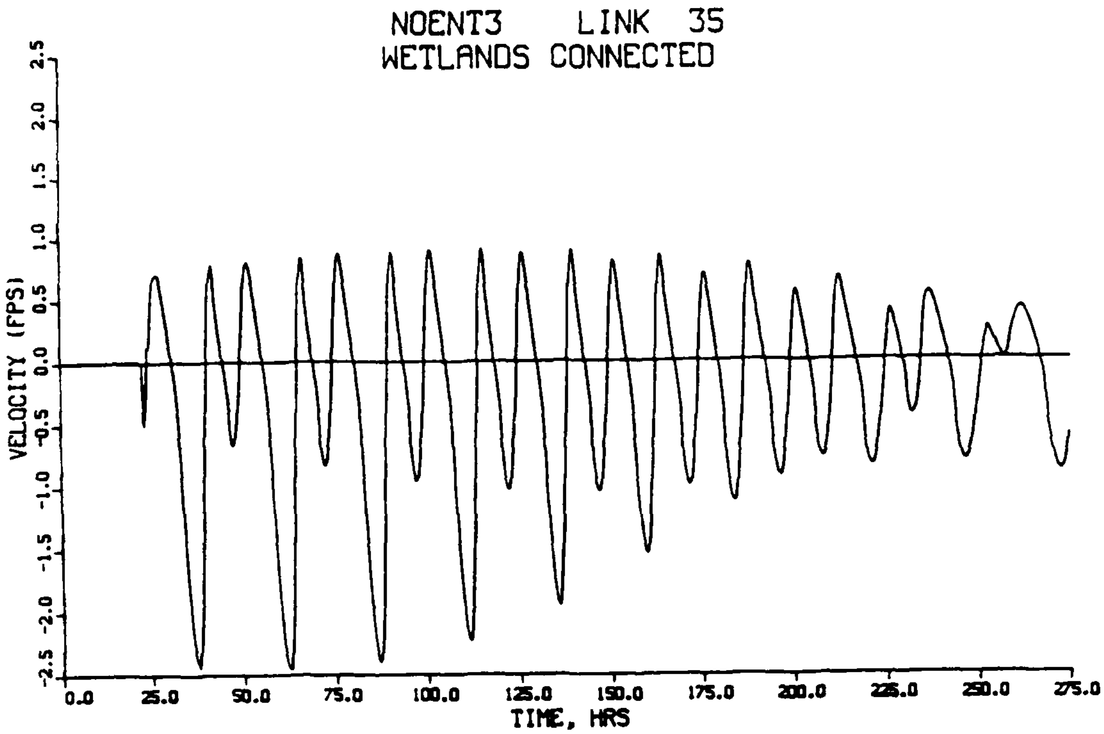


Figure L23. Average channel velocities in Outer Bolsa Bay under non-navigable entrance closed, no by-pass connector to marina conditions

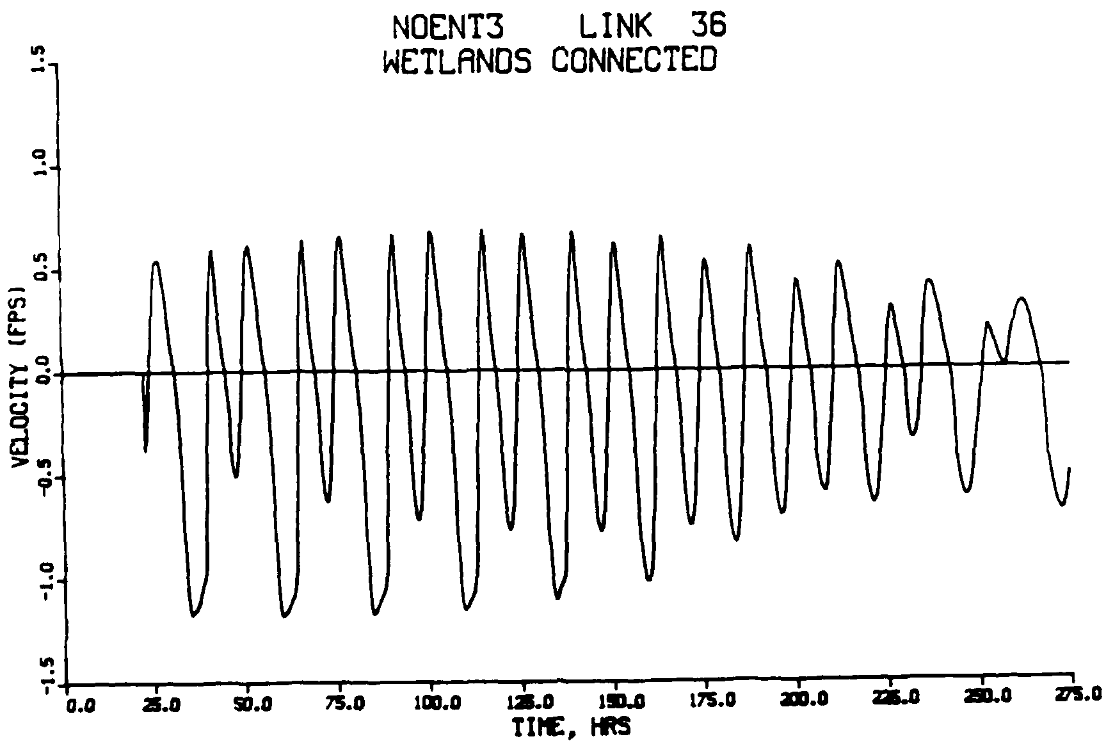


Figure L24. Average channel velocities in Outer Bolsa Bay under non-navigable entrance closed, no by-pass connector to marina conditions

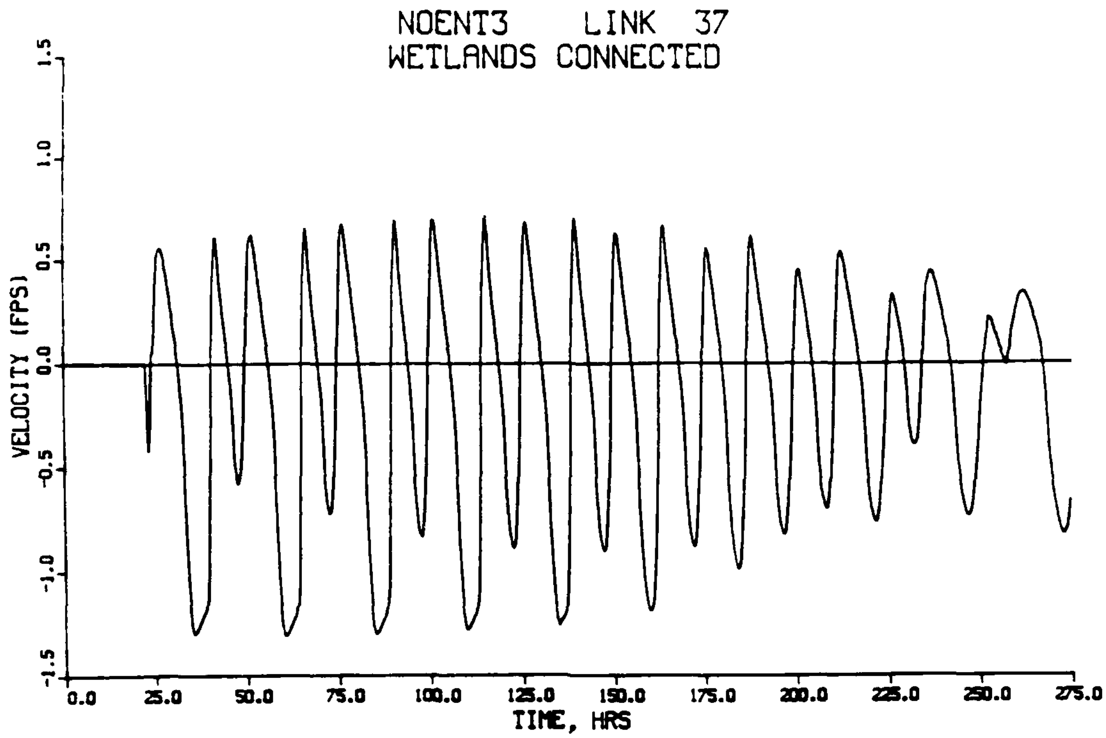


Figure L25. Average channel velocities in Outer Bolsa Bay under non-navigable entrance closed, no by-pass connector to marina conditions

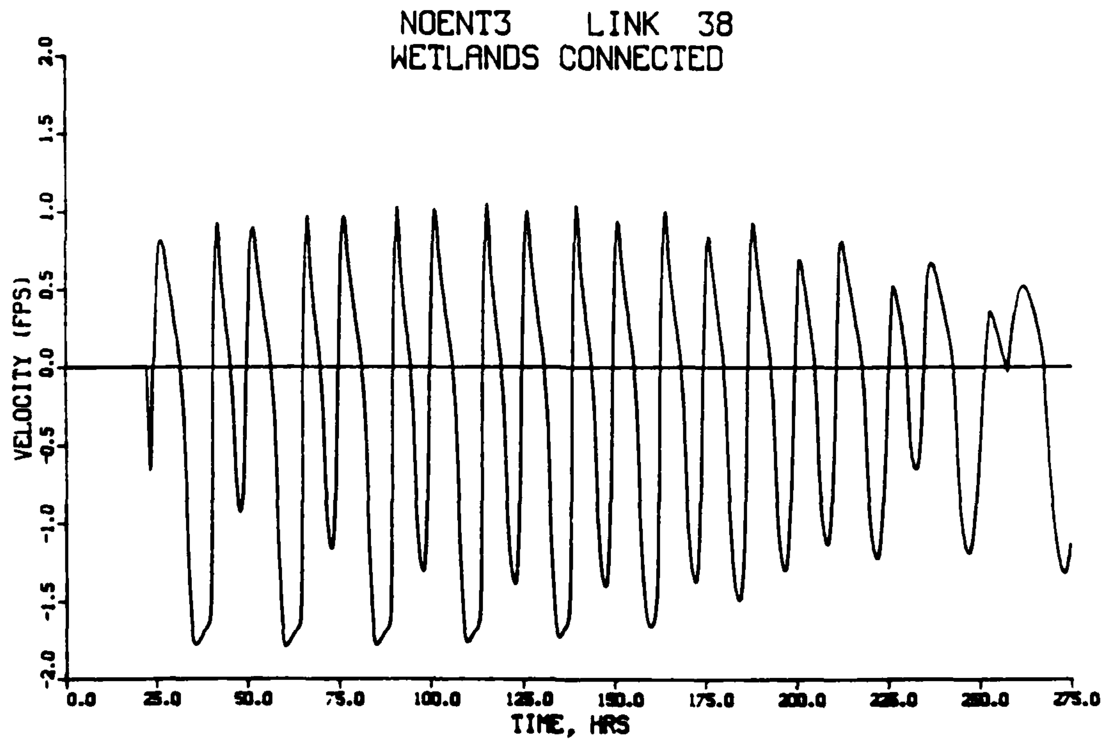


Figure L26. Average channel velocities in Outer Bolsa Bay under non-navigable entrance closed, no by-pass connector to marina conditions

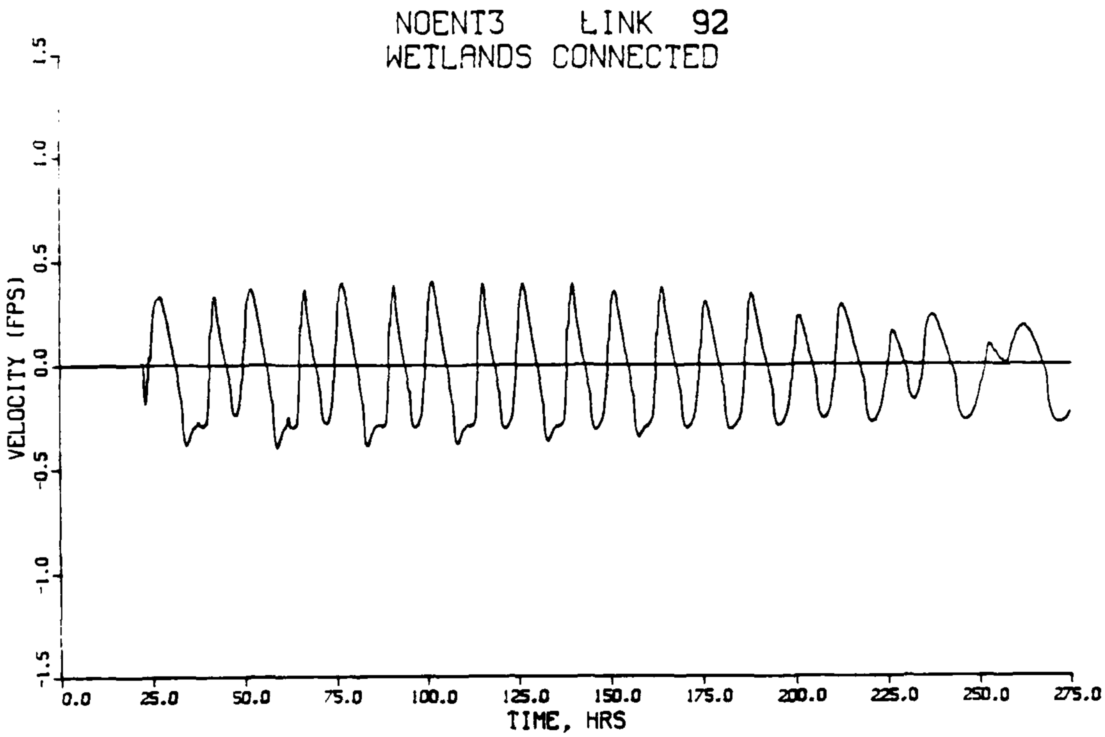


Figure L27. Average channel velocities in EGG-WFCC under non-navigable entrance closed, no by-pass connector to marina conditions

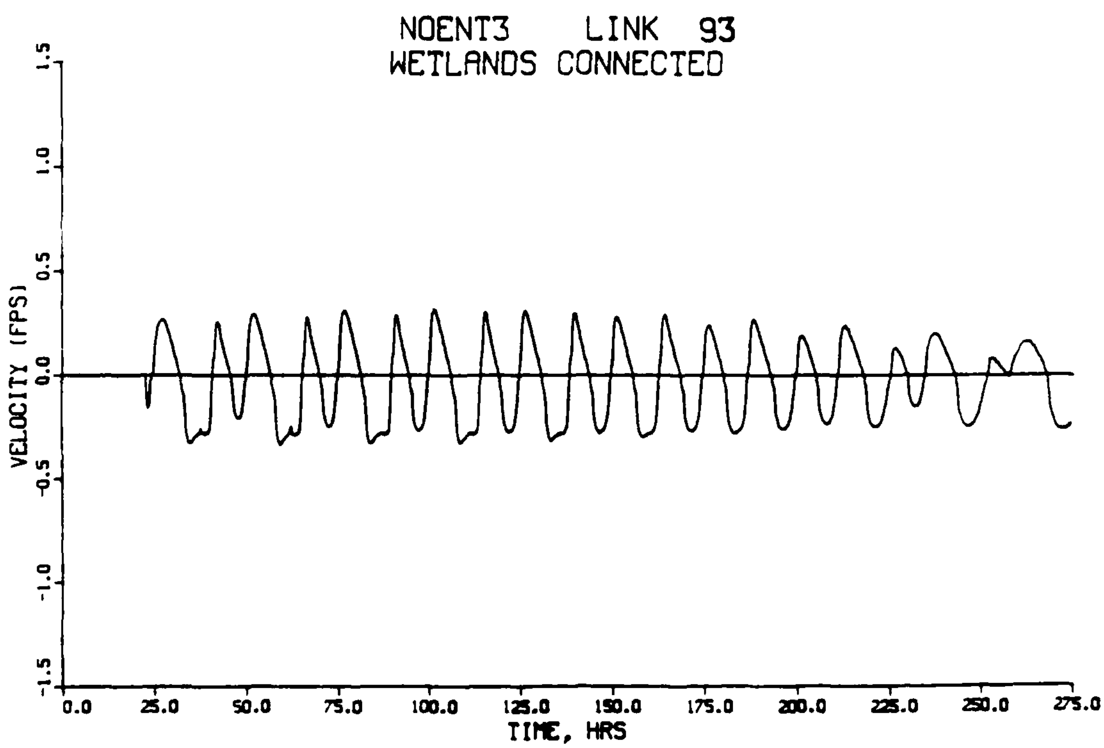


Figure L28. Average channel velocities in EGG-WFCC under non-navigable entrance closed, no by-pass connector to marina conditions

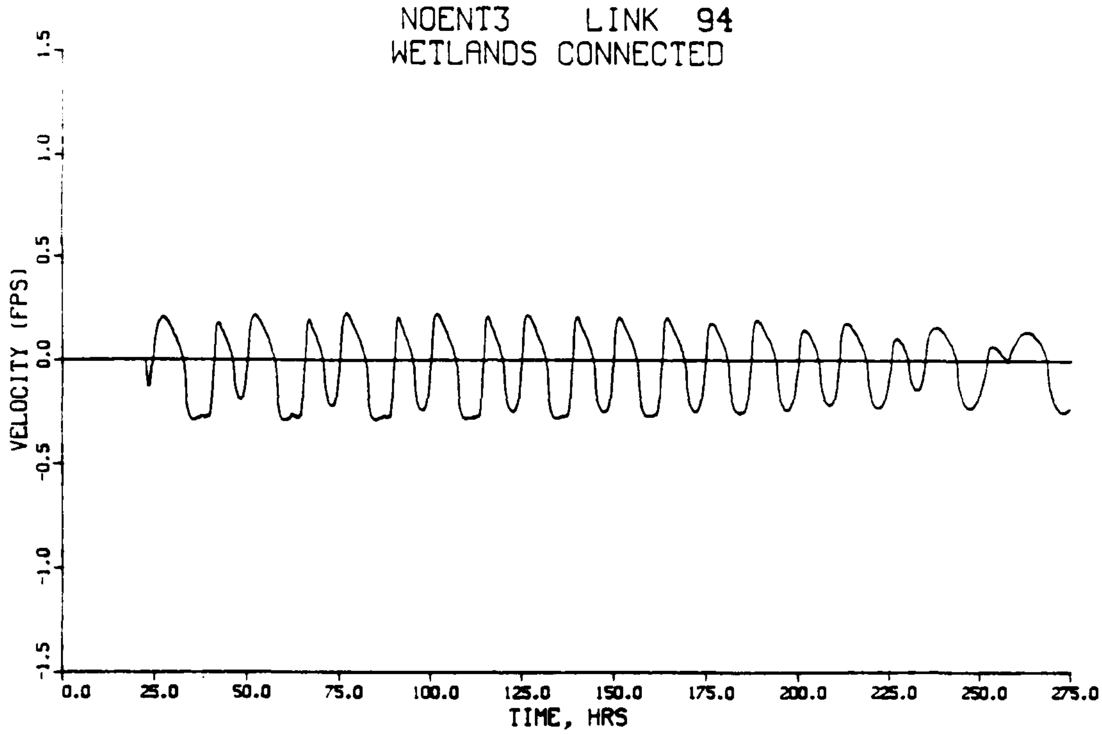


Figure L29. Average channel velocities in EGG-WFCC under non-navigable entrance closed, no by-pass connector to marina conditions

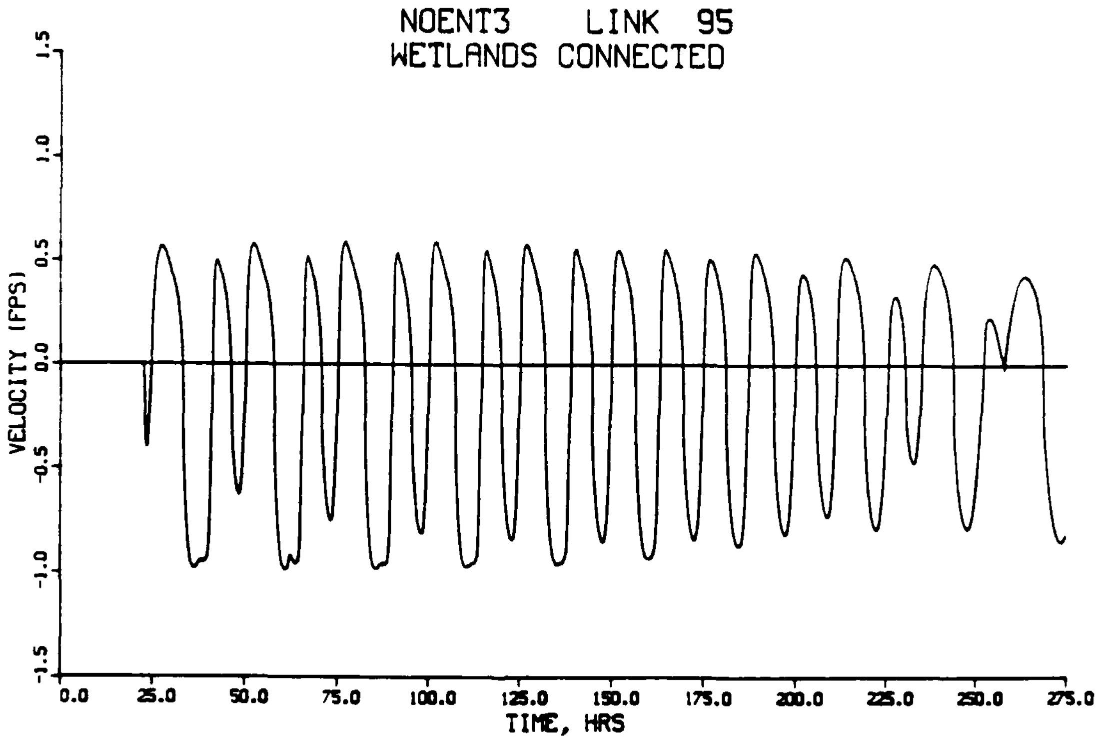


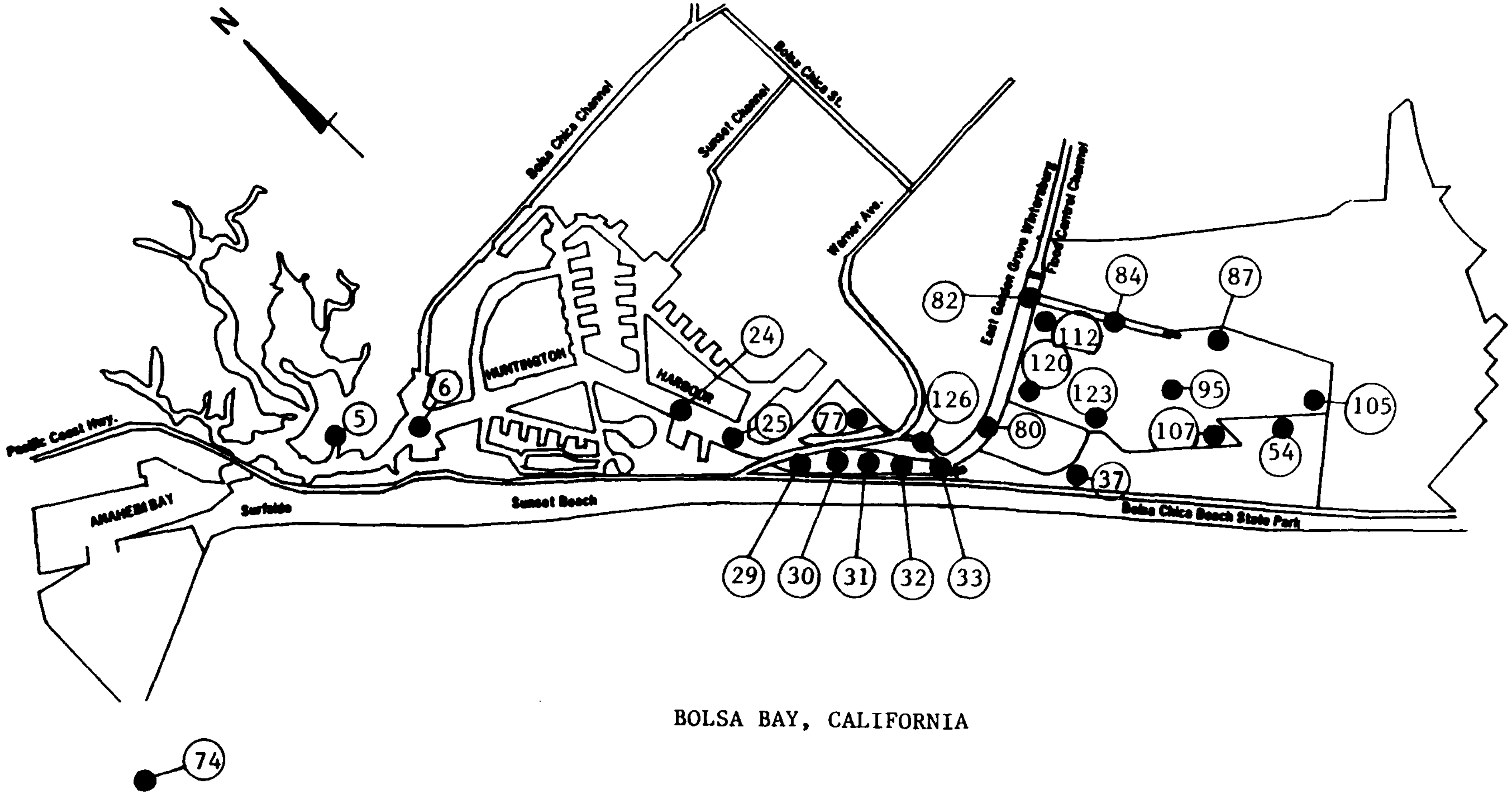
Figure L30. Average channel velocities in channel to muted wetlands under non-navigable entrance closed, no by-pass connector to marina conditions

APPENDIX M:

NOENT4

NON-NAVIGABLE ENTRANCE CHANNEL CLOSED
AND
BY-PASS CONNECTOR CHANNEL TO MARINA

WATER SURFACE ELEVATIONS



BOLSA BAY, CALIFORNIA

NOENT4
Location of nodes for displaying water surface elevations
under non-navigable entrance channel closed and by-pass connector channel to marina

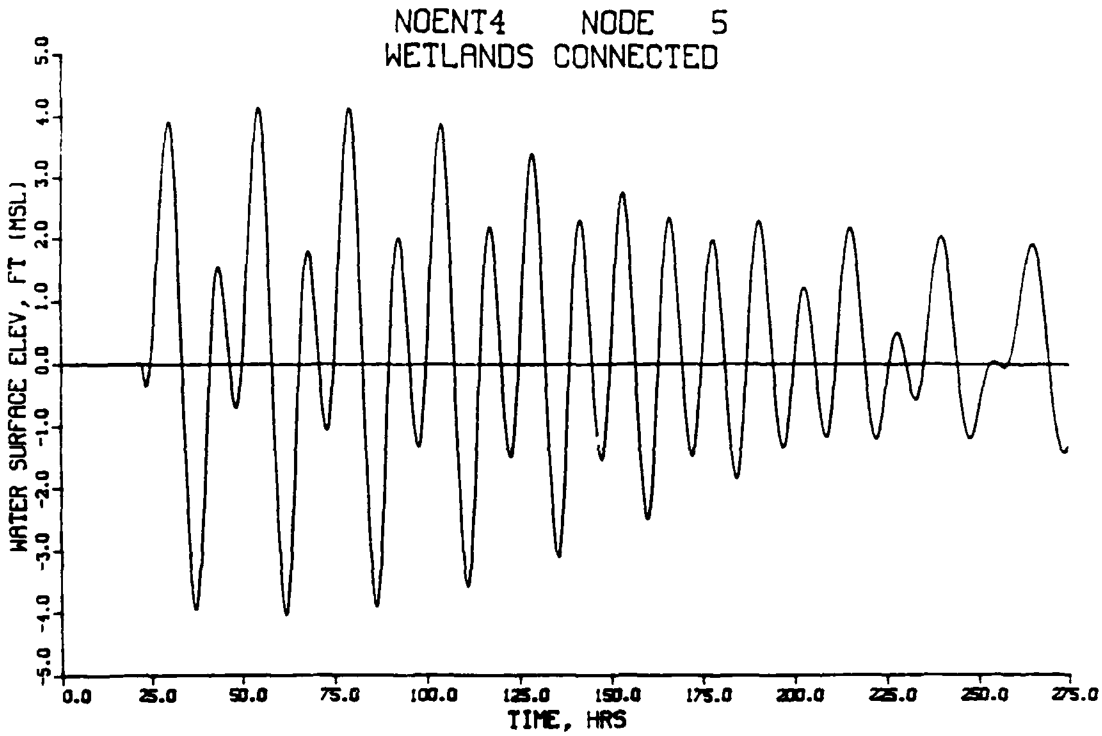


Figure M1. Tidal elevations in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

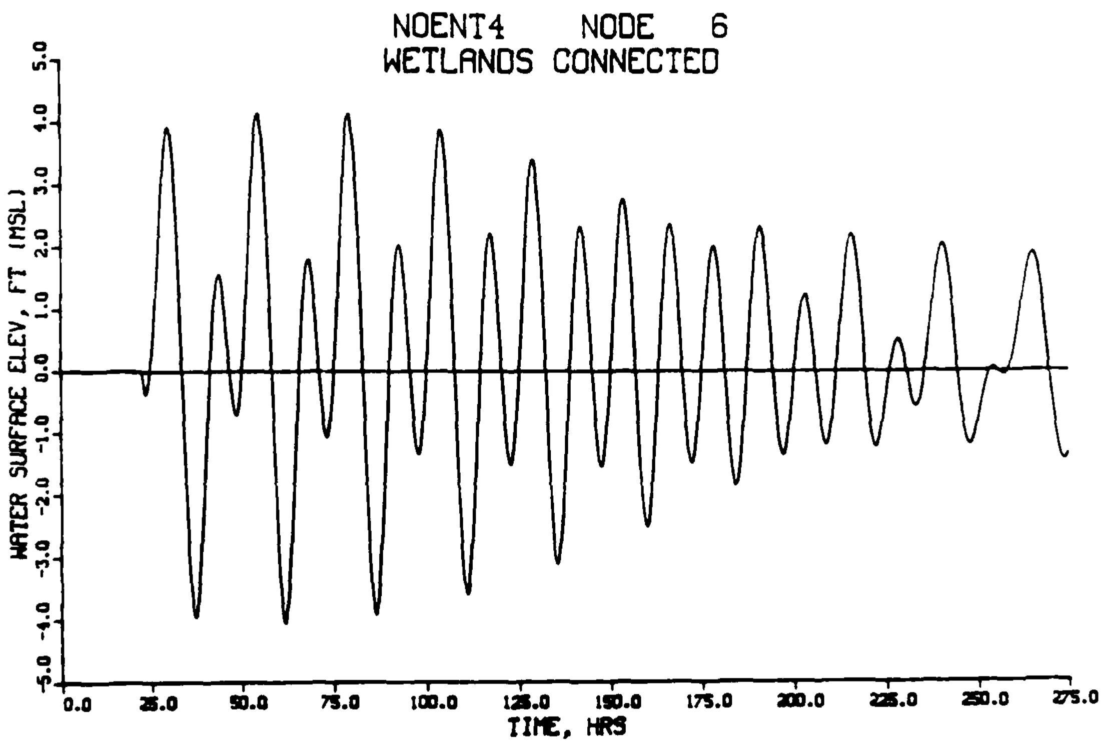


Figure M2. Tidal elevations in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

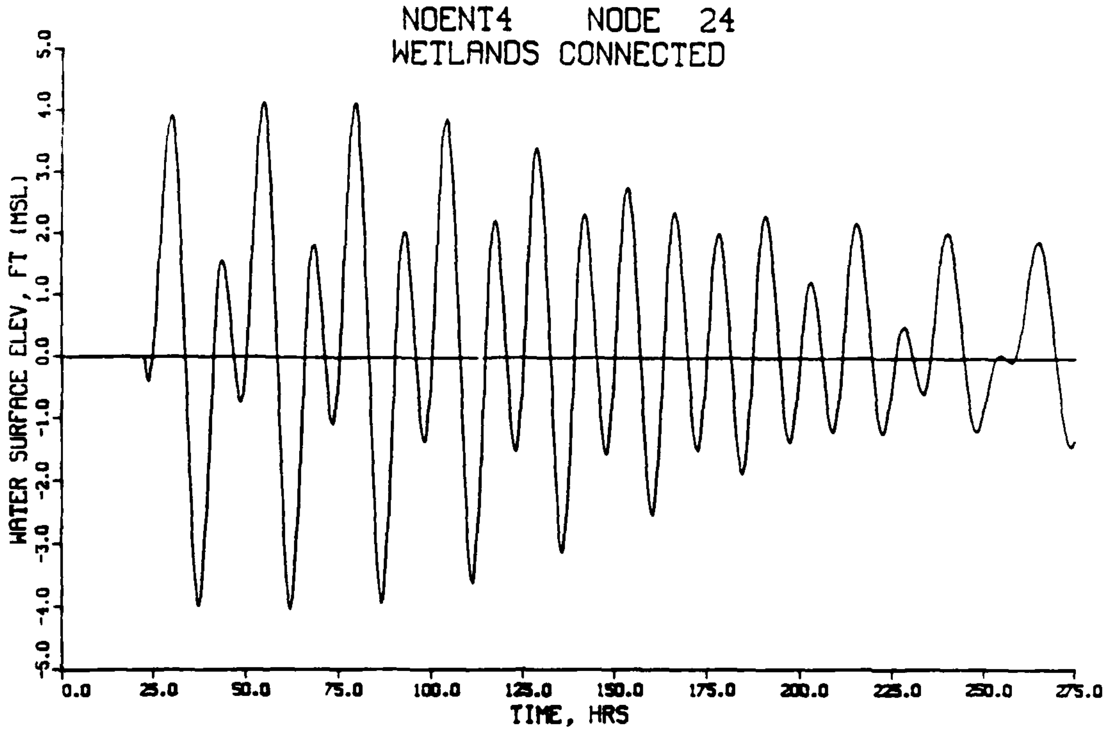


Figure M3. Tidal elevations in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

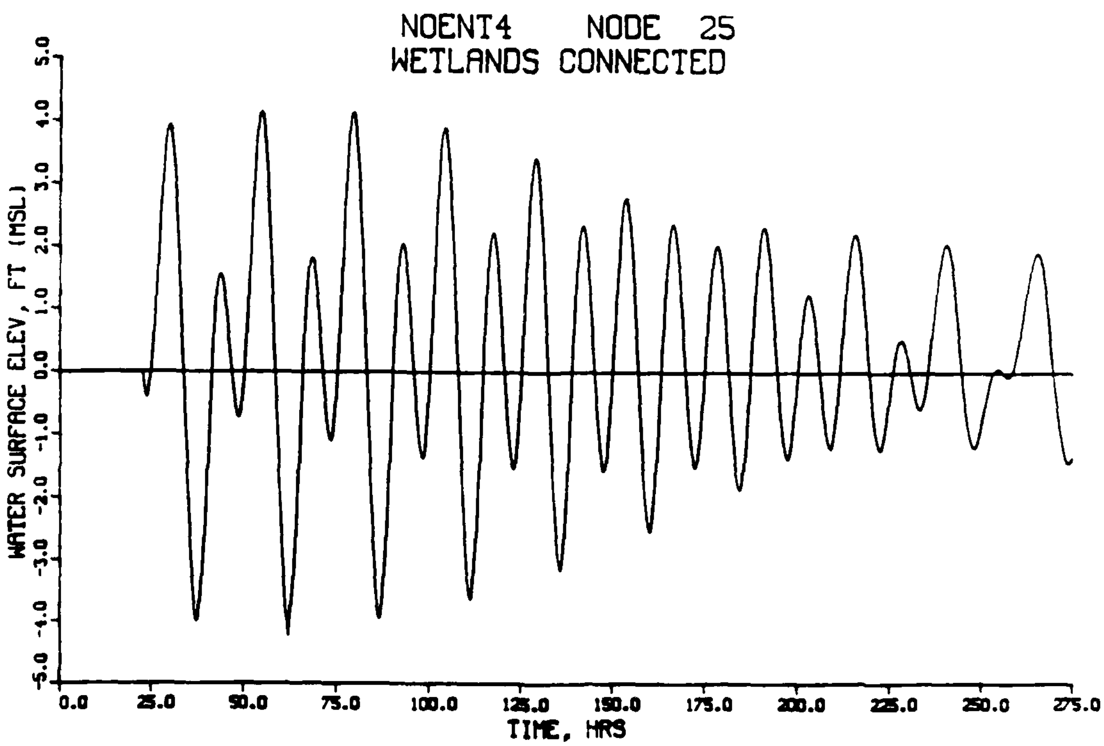


Figure M4. Tidal elevations in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

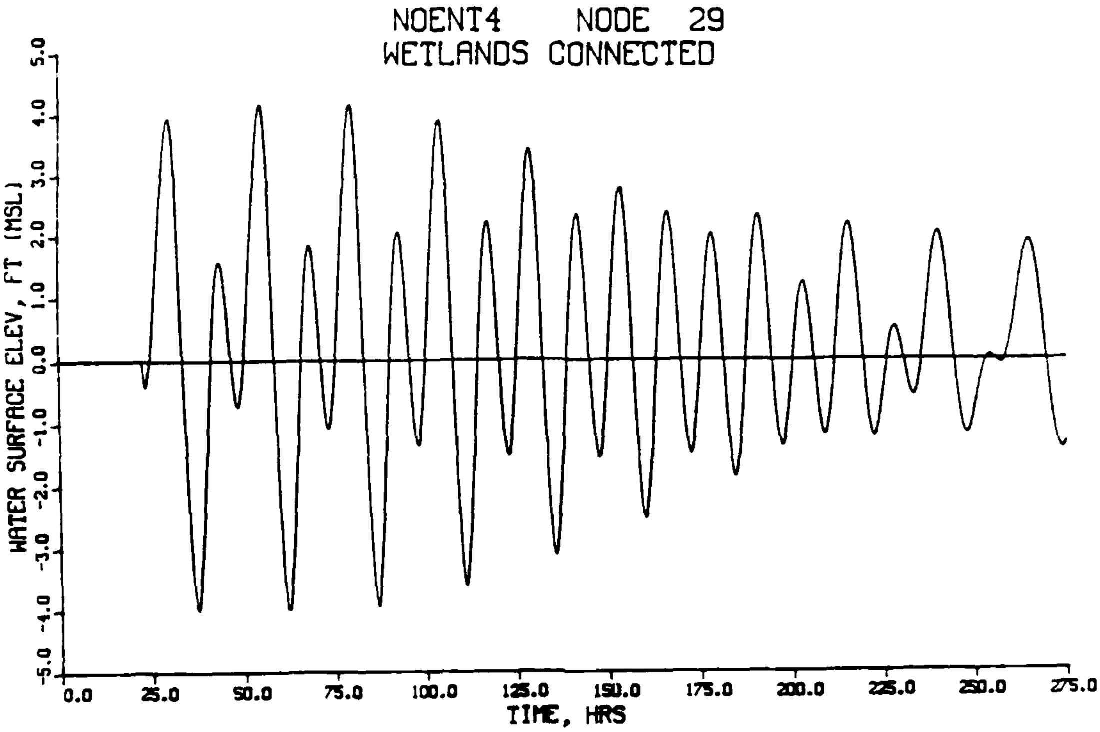


Figure M5. Tidal elevations in Outer Bolsa Bay under non-navigable entrance closed, by-pass connector to marina conditions

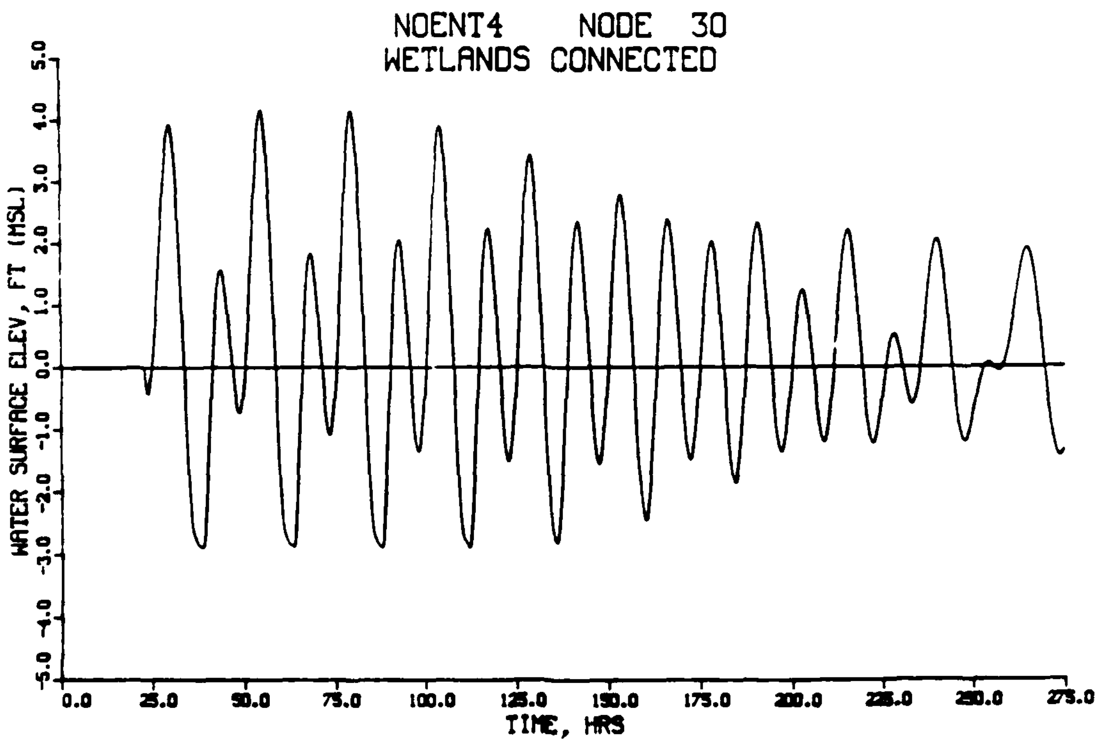


Figure M6. Tidal elevations in Outer Bolsa Bay under non-navigable entrance closed, by-pass connector to marina conditions

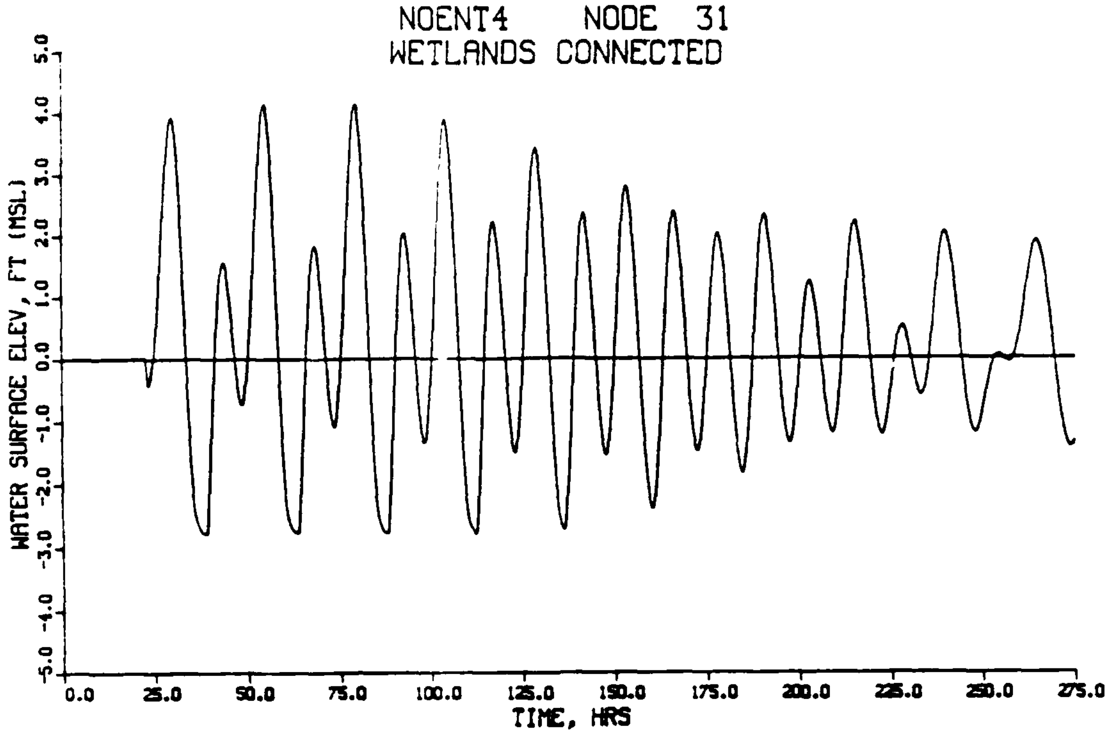


Figure M7. Tidal elevations in Outer Bolsa Bay under non-navigable entrance closed, by-pass connector to marina conditions

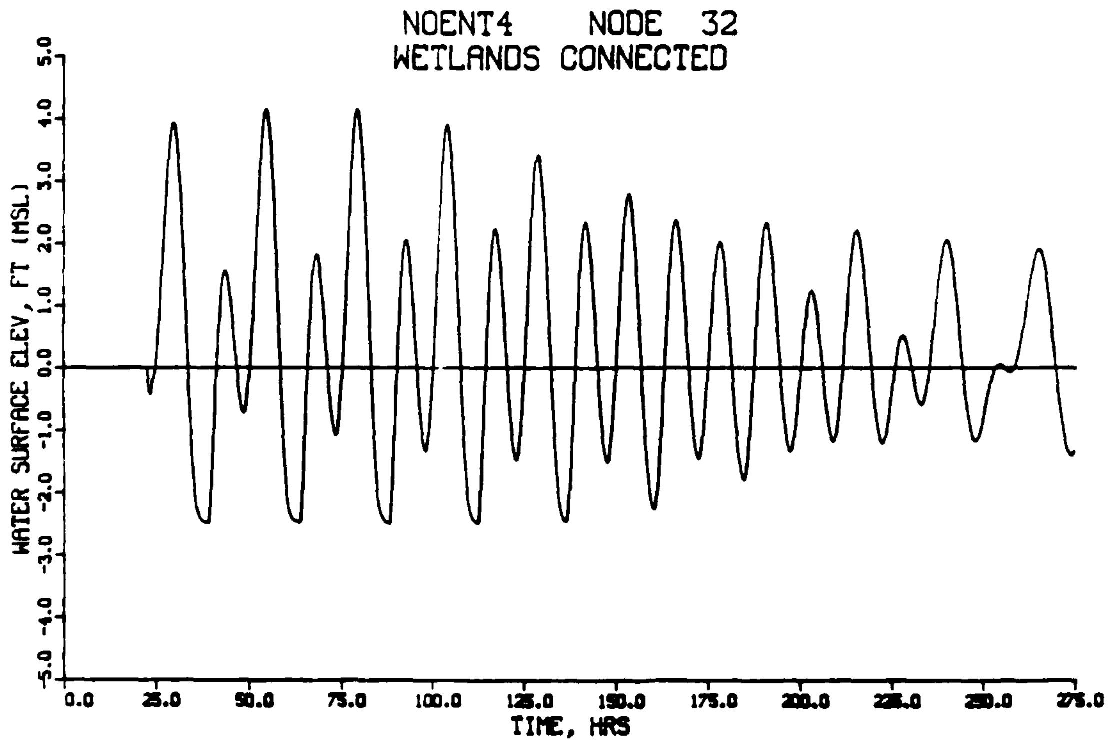


Figure M8. Tidal elevations in Outer Bolsa Bay under non-navigable entrance closed, by-pass connector to marina conditions

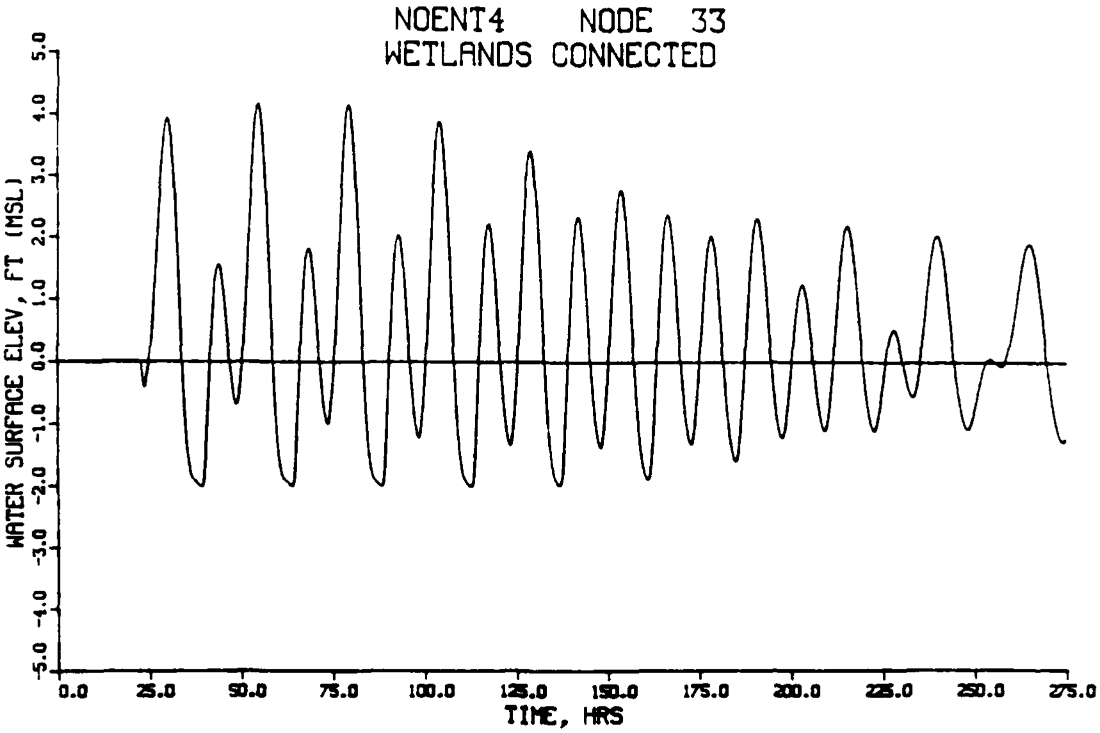


Figure M9. Tidal elevations in Outer Bolsa Bay under non-navigable entrance closed, by-pass connector to marina conditions

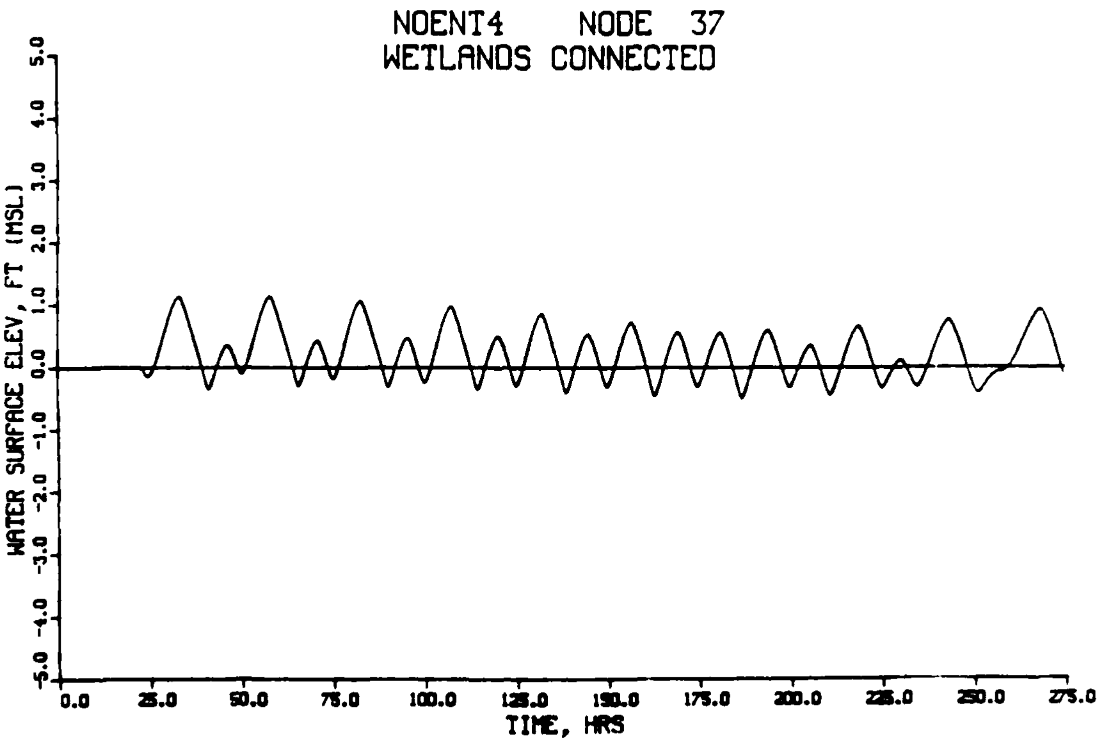


Figure M10. Tidal elevations in Inner Bolsa Bay under non-navigable entrance closed, by-pass connector to marina conditions

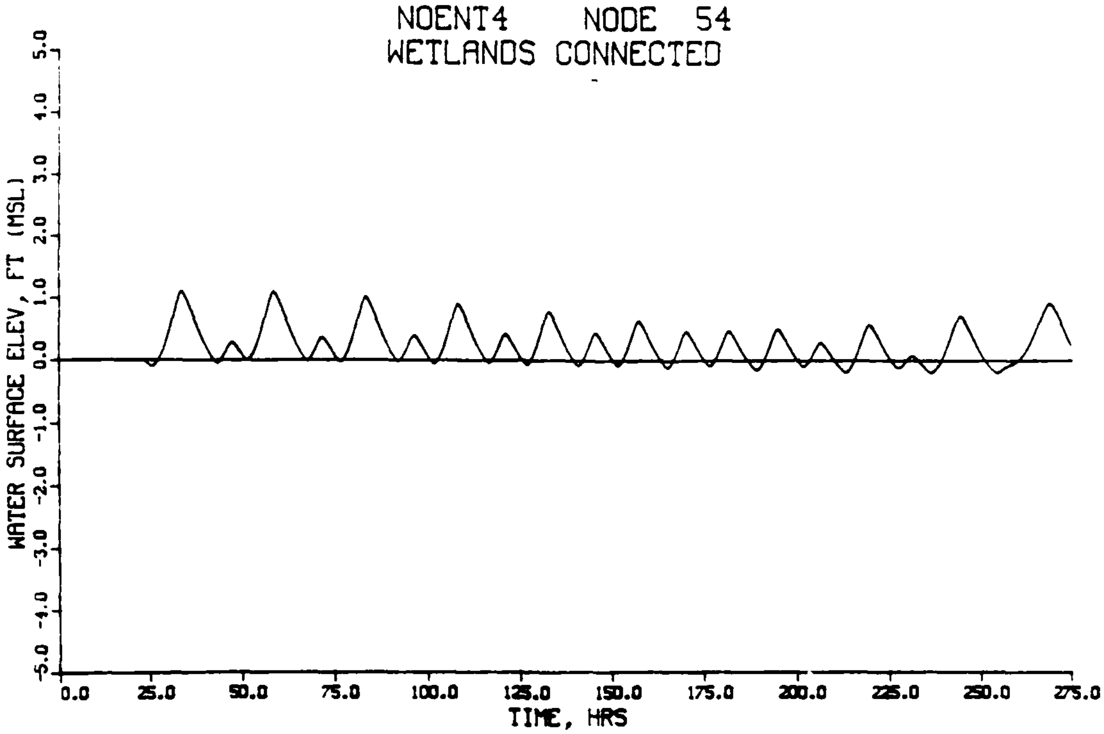


Figure M11. Tidal elevations in DFG muted tidal cell under non-navigable entrance closed, by-pass connector to marina conditions

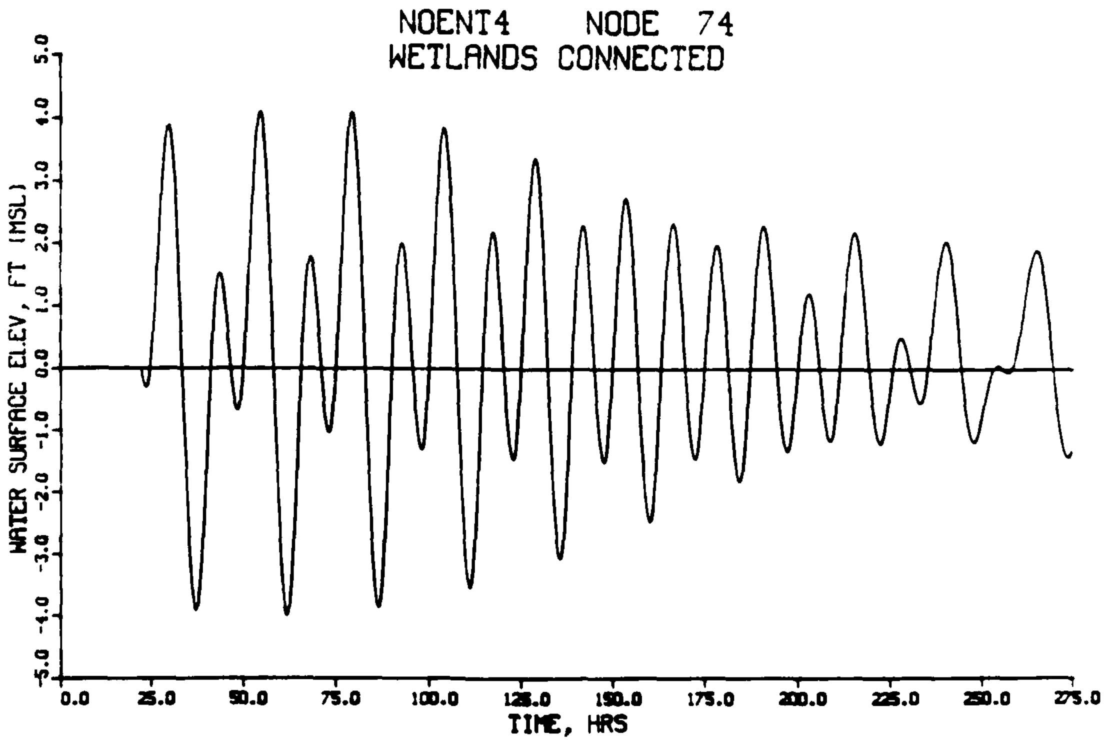


Figure M12. Tidal elevations in Pacific Ocean, driving non-navigable entrance closed, by-pass connector to marina conditions

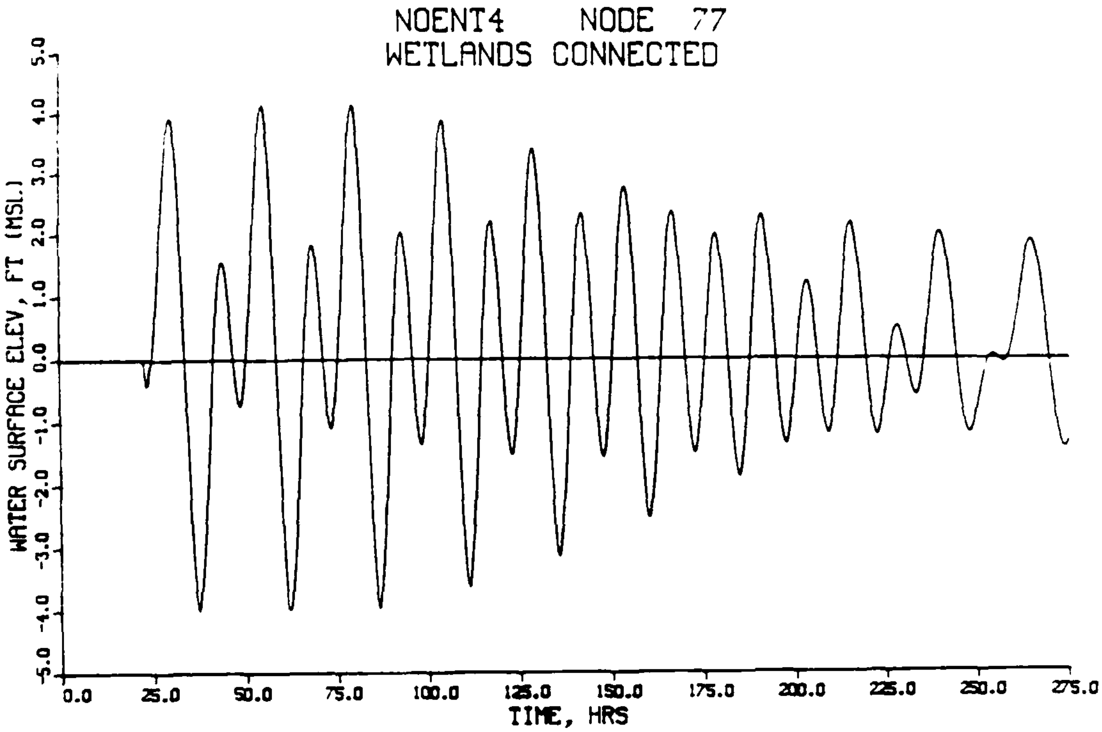


Figure M13. Tidal elevations in proposed marina under non-navigable entrance closed, by-pass connector to marina conditions

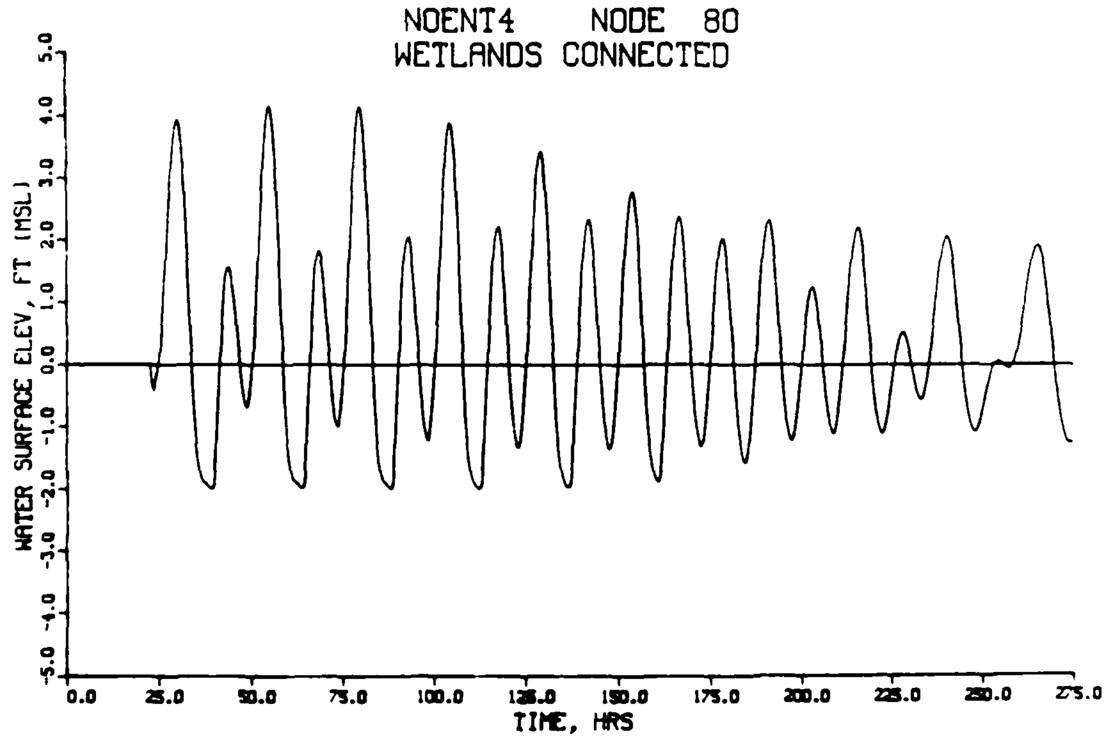


Figure M14. Tidal elevations in EGG-WFCC under non-navigable entrance closed, by-pass connector to marina conditions

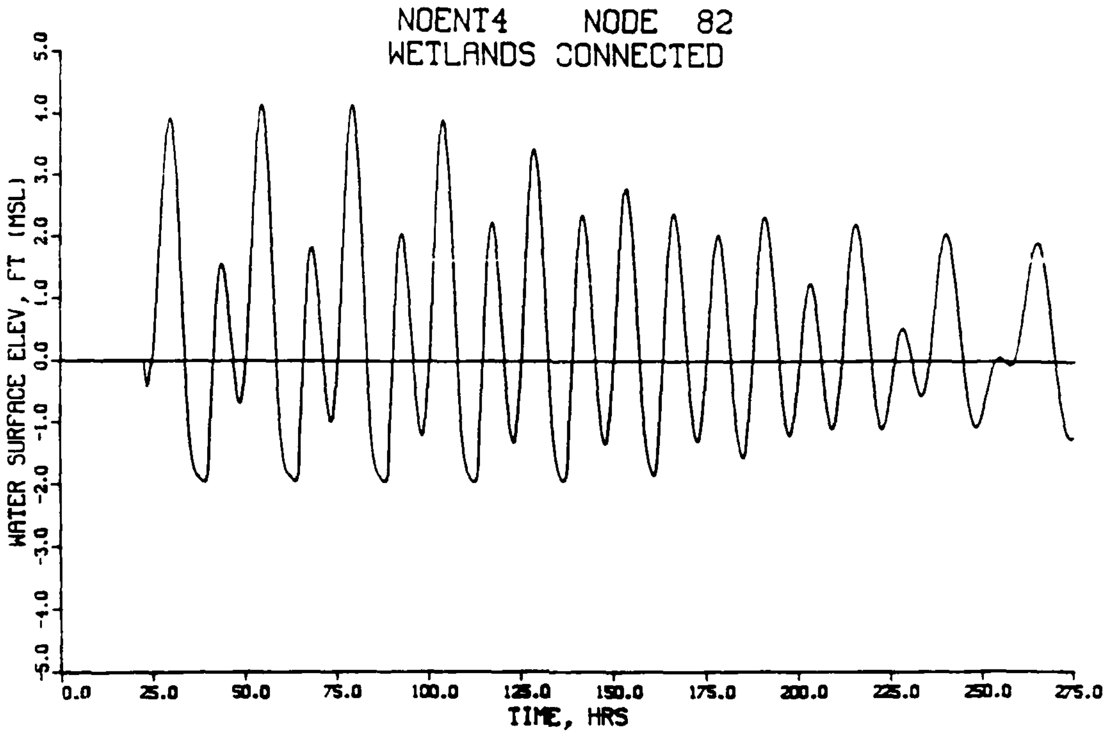


Figure M15. Tidal elevations in EGG-WFCC under non-navigable entrance closed, by-pass connector to marina conditions

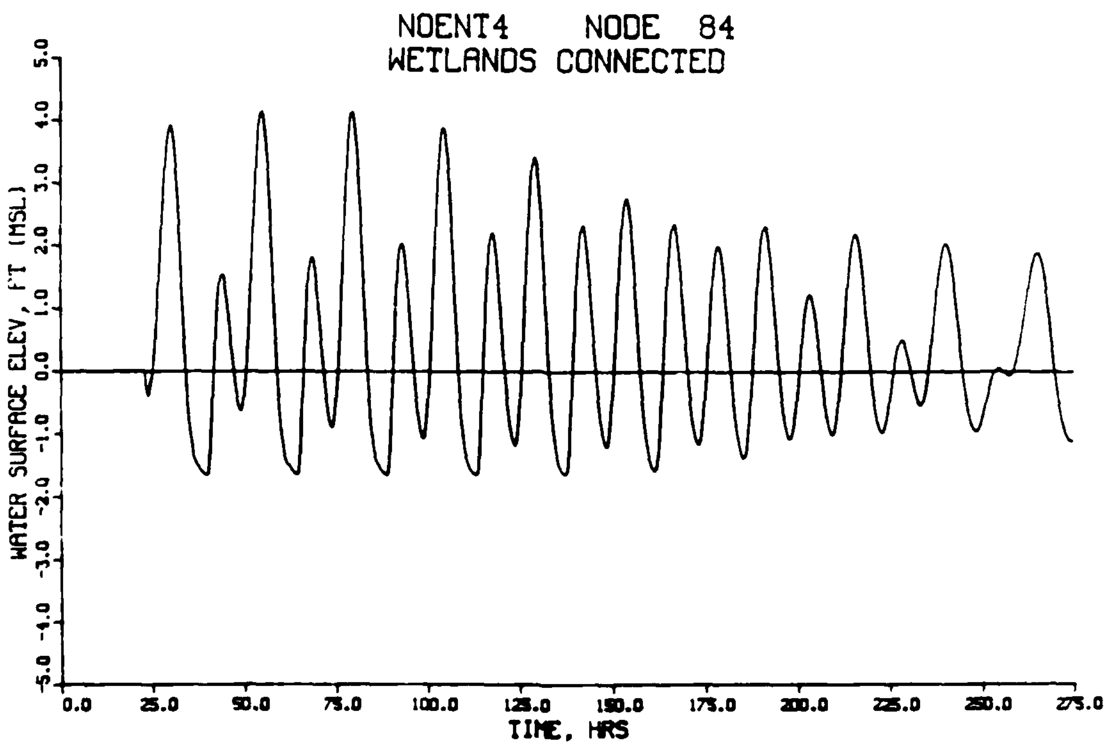


Figure M16. Tidal elevations in channel to proposed muted wetlands under non-navigable entrance closed, by-pass connector to marina conditions

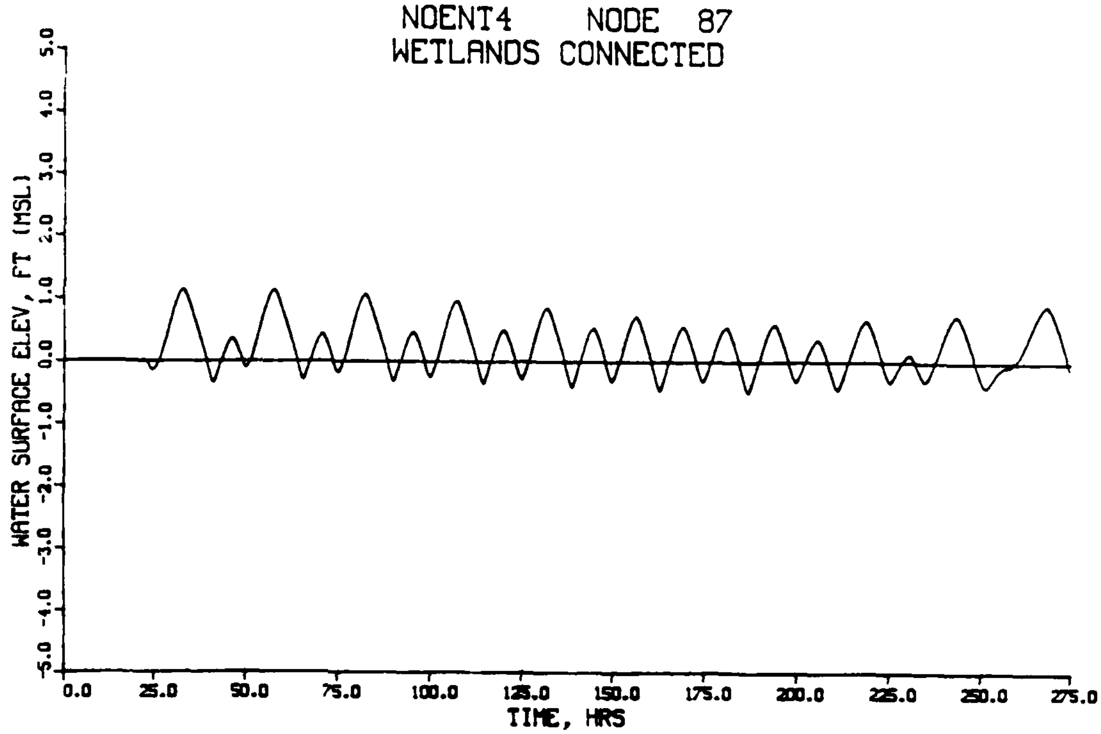


Figure M17. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance closed, by-pass connector to marina conditions

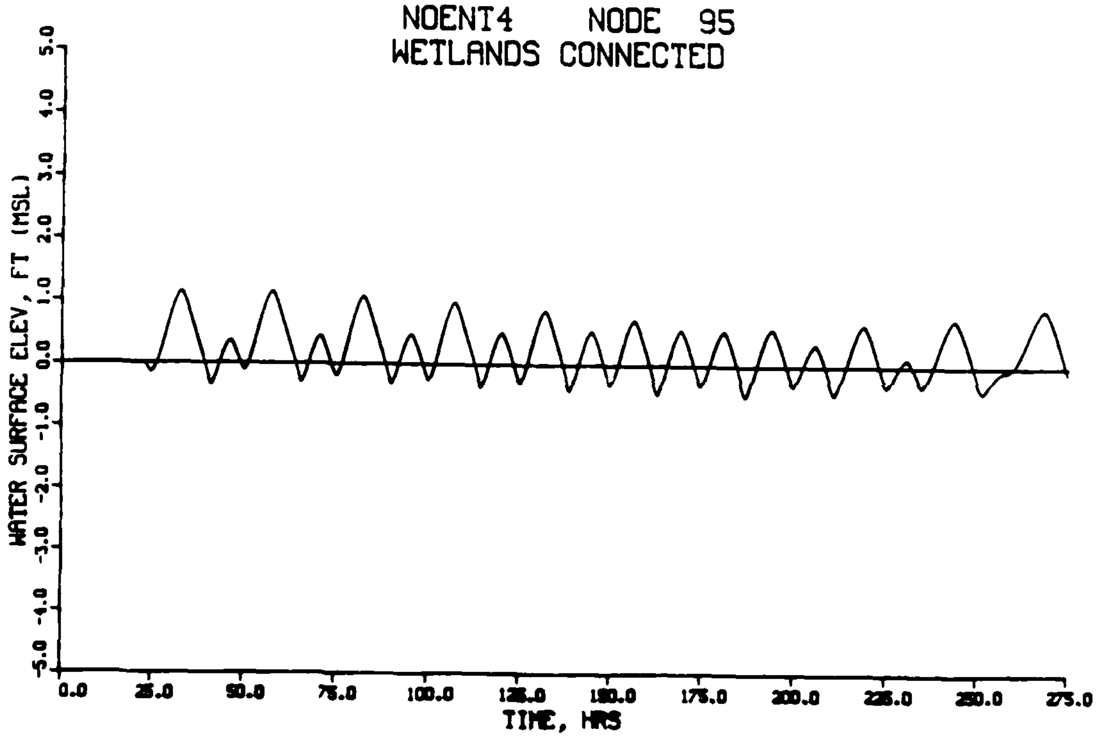


Figure M18. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance closed, by-pass connector to marina conditions

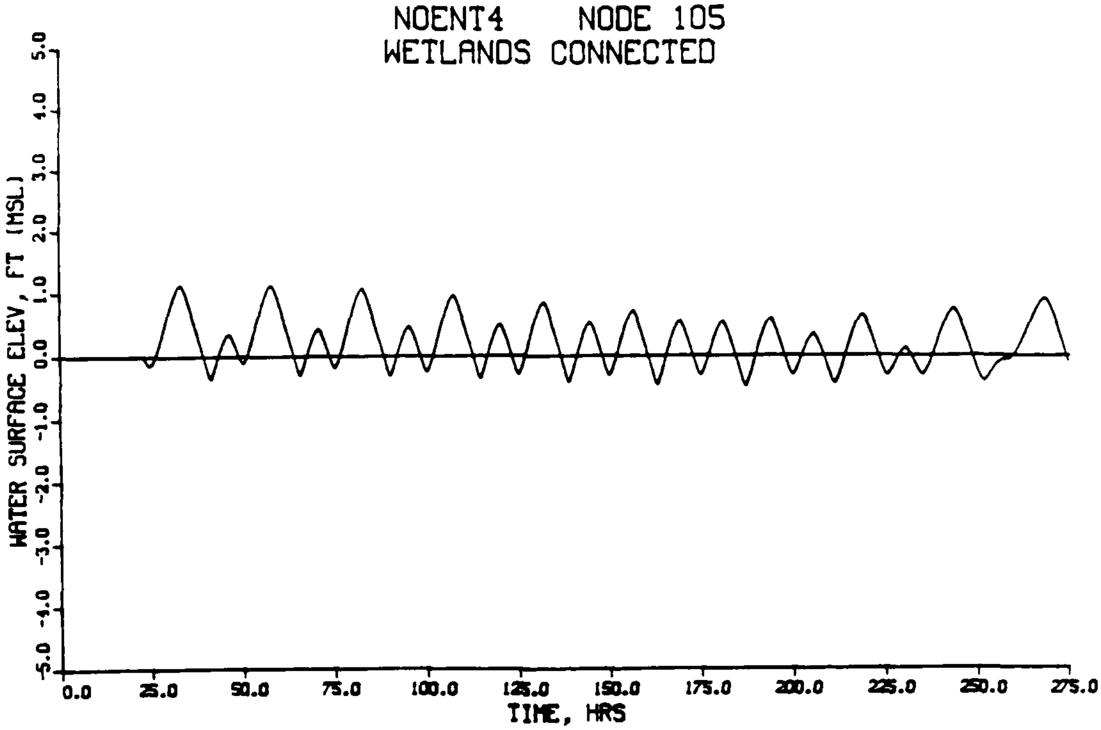


Figure M19. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance closed, by-pass connector to marina conditions

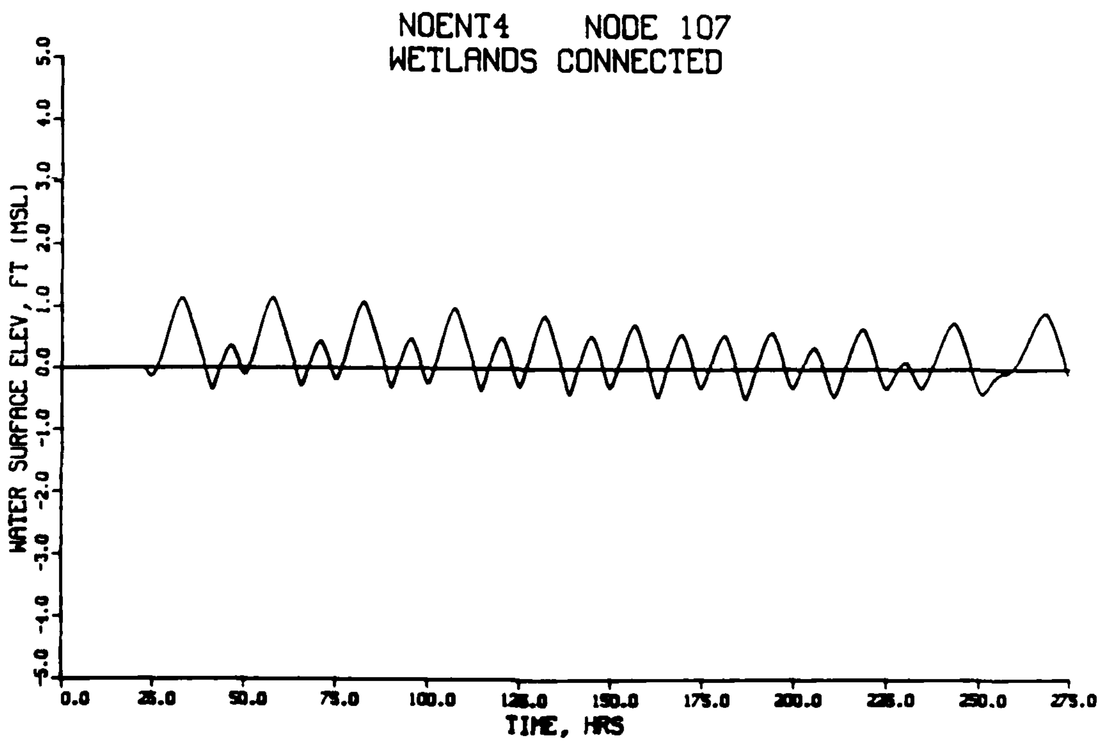


Figure M20. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance closed, by-pass connector to marina conditions

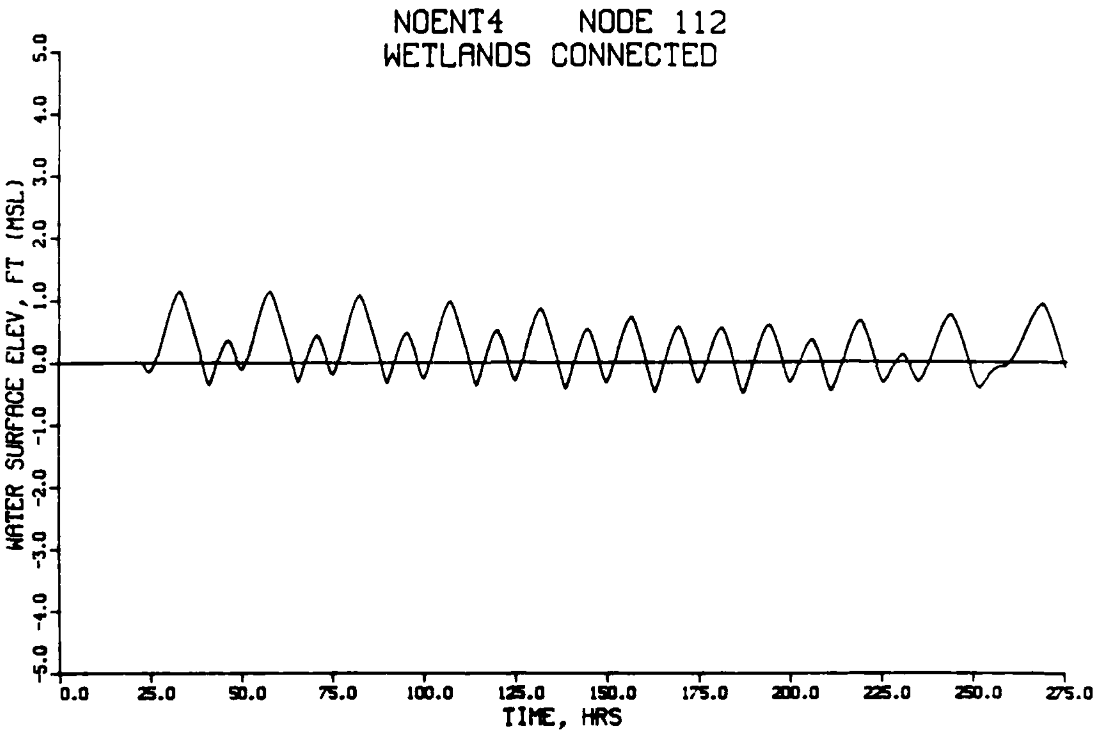


Figure M21. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance closed, by-pass connector to marina conditions

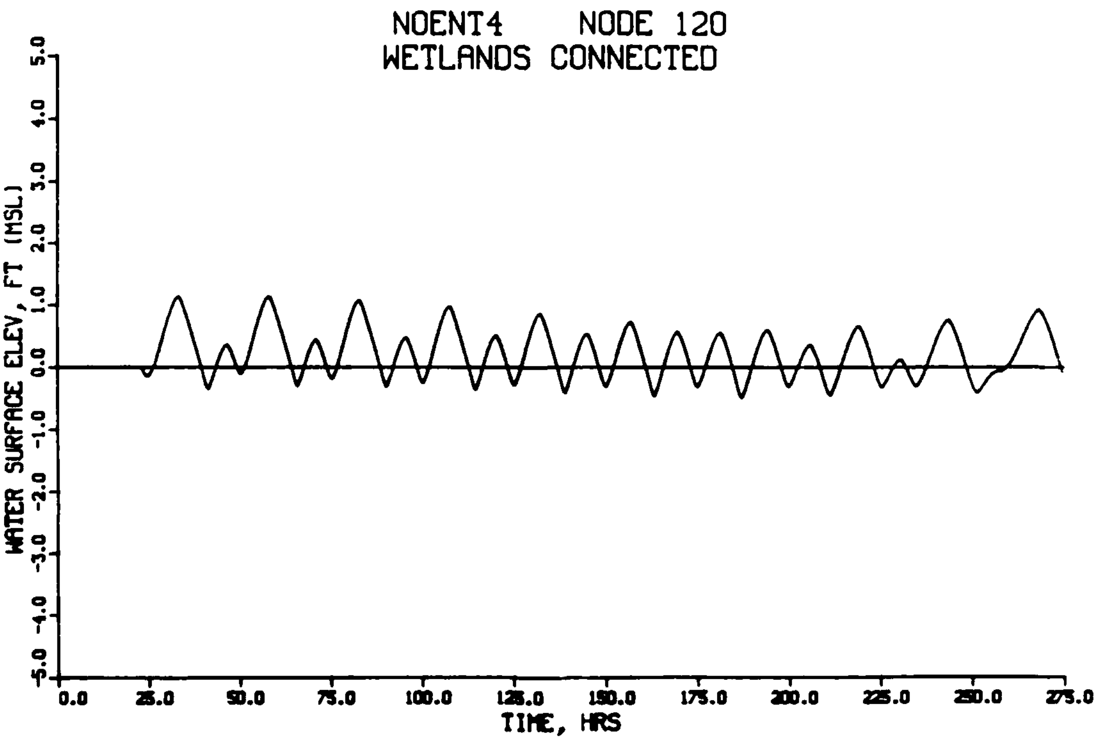


Figure M22. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance closed, by-pass connector to marina conditions

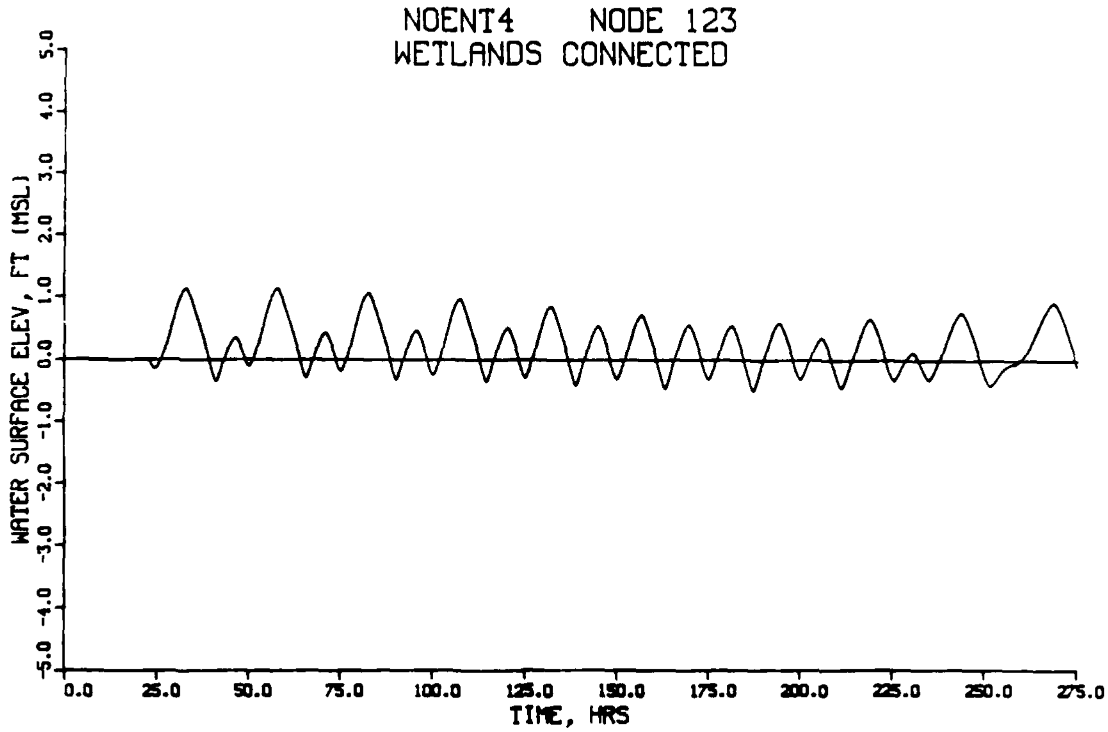


Figure M23. Tidal elevations in proposed muted tidal wetlands under non-navigable entrance closed, by-pass connector to marina conditions

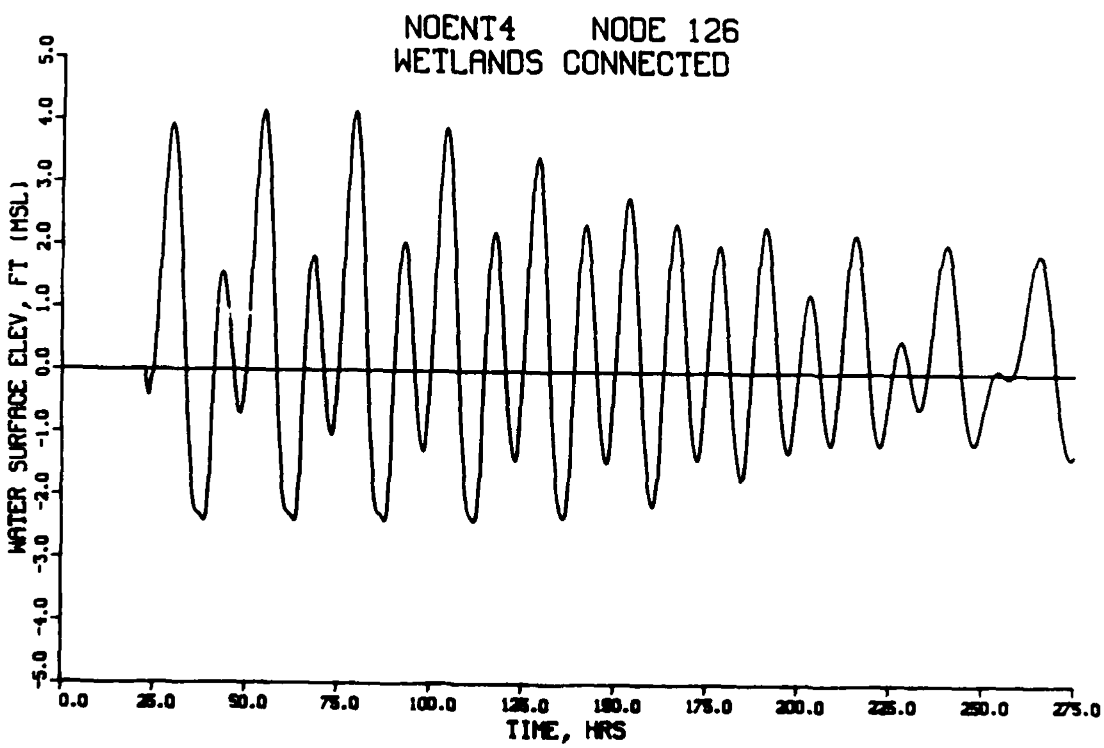


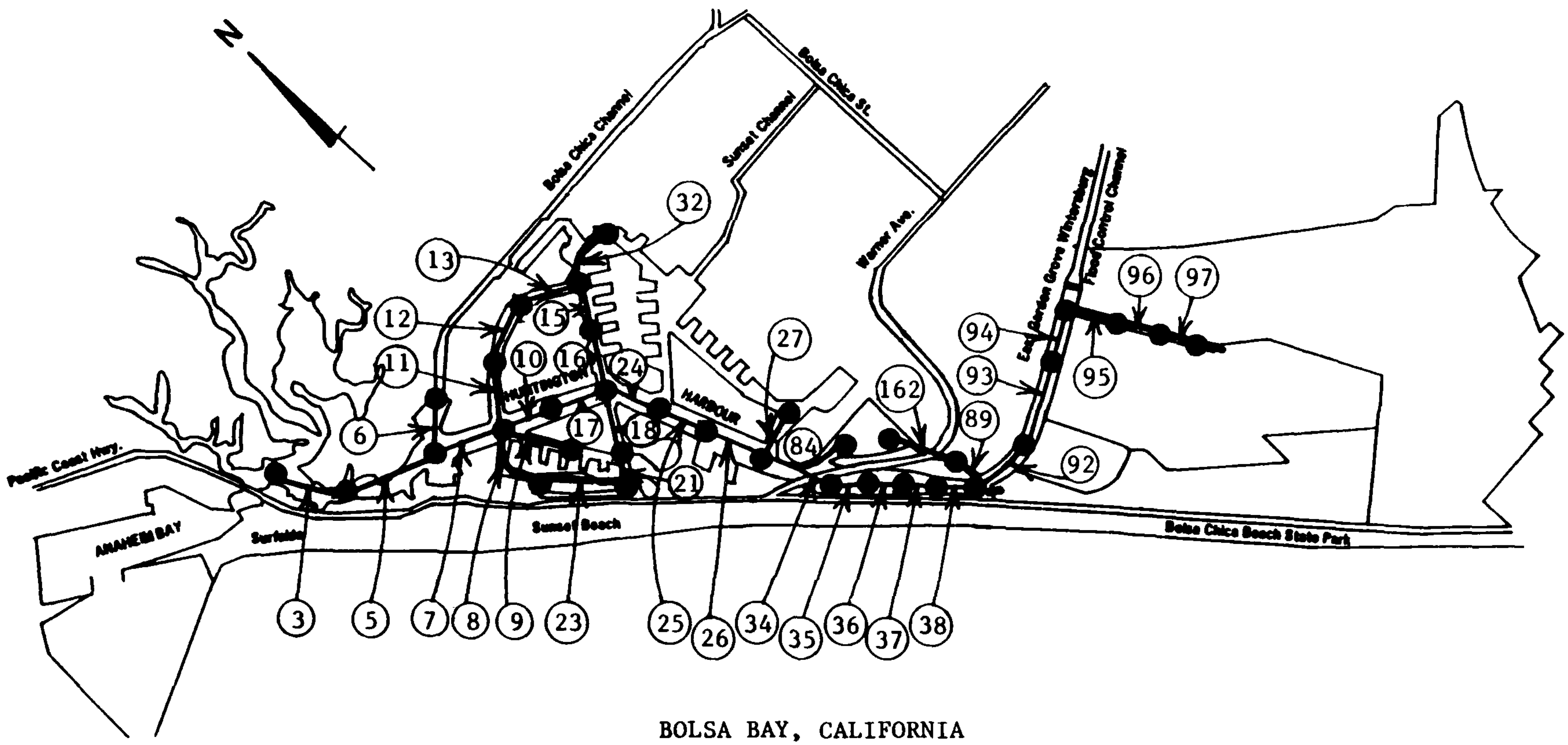
Figure M24. Tidal elevations in by-pass connector channel to marina under non navigable entrance closed, by-pass connector to marina conditions

APPENDIX N:

NOENT4

NON-NAVIGABLE ENTRANCE CHANNEL CLOSED
AND
BY-PASS CONNECTOR CHANNEL TO MARINA

AVERAGE CHANNEL VELOCITIES



BOLSA BAY, CALIFORNIA

NOENT4
Location of links for displaying average channel velocities
under non-navigable entrance channel closed and by-pass connector channel to marina conditions

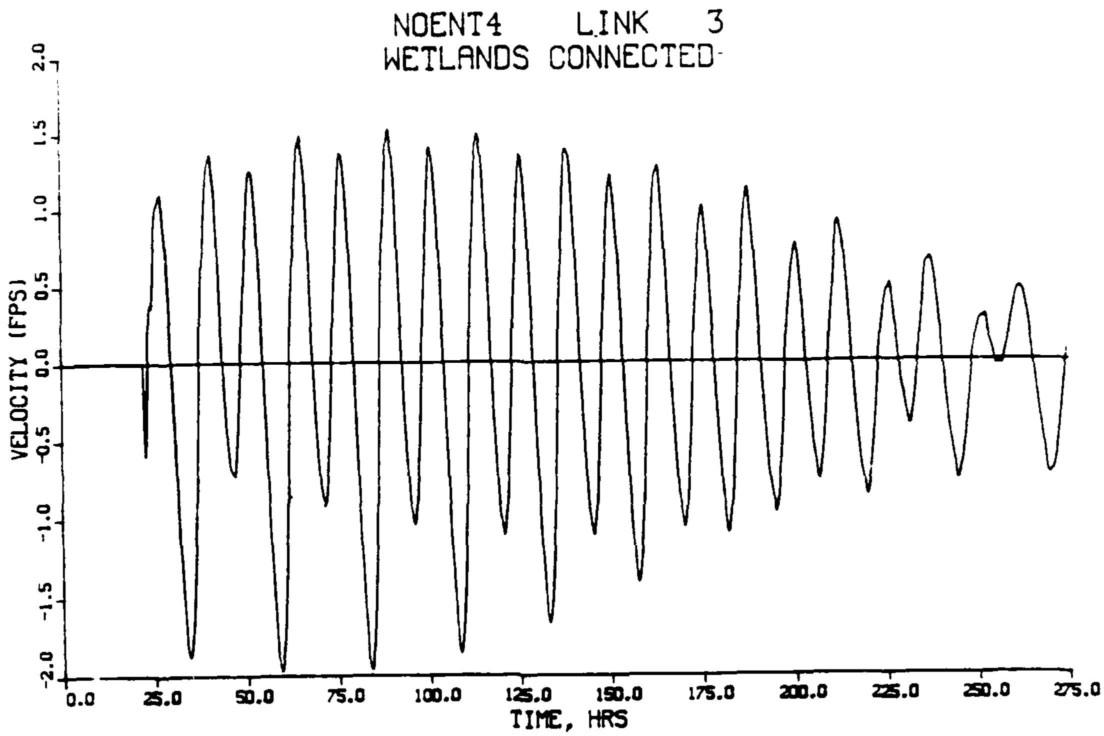


Figure N1. Average channel velocities in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

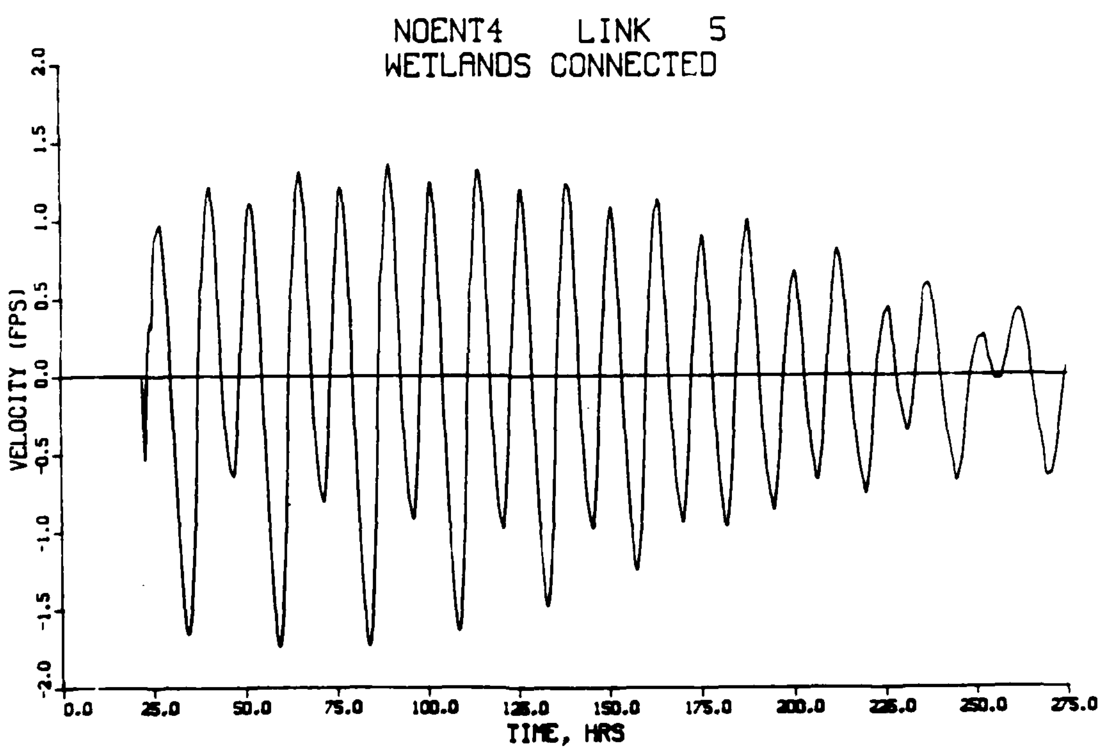


Figure N2. Average channel velocities in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

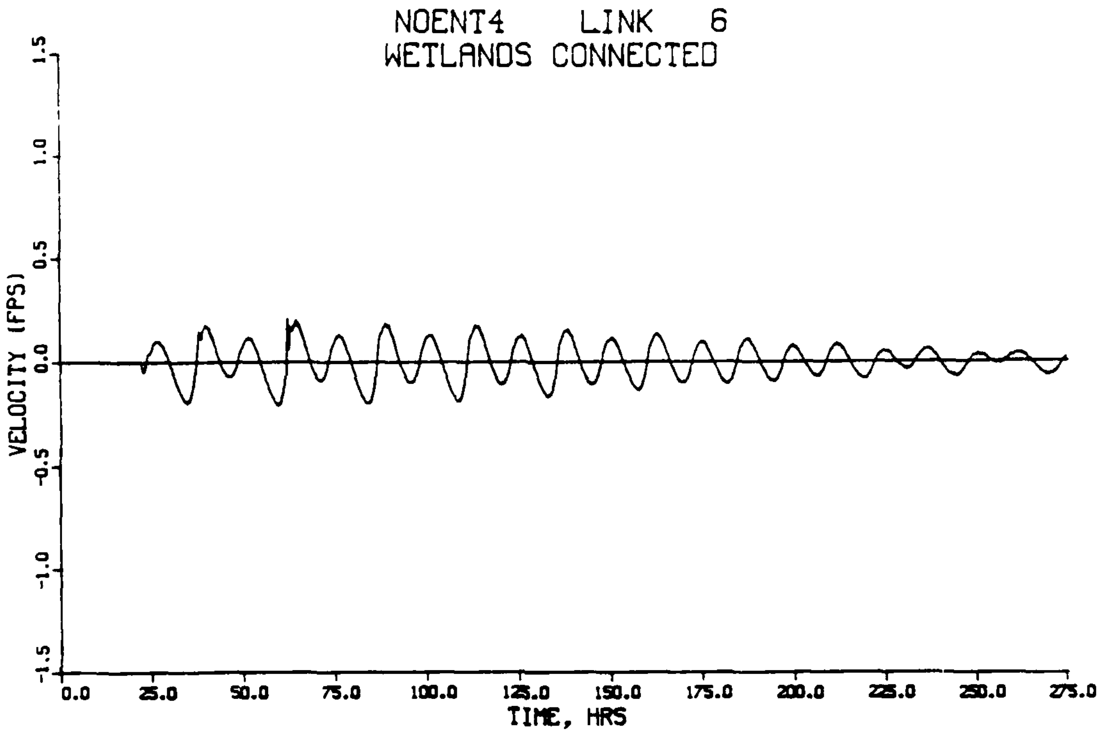


Figure N3. Average channel velocities in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

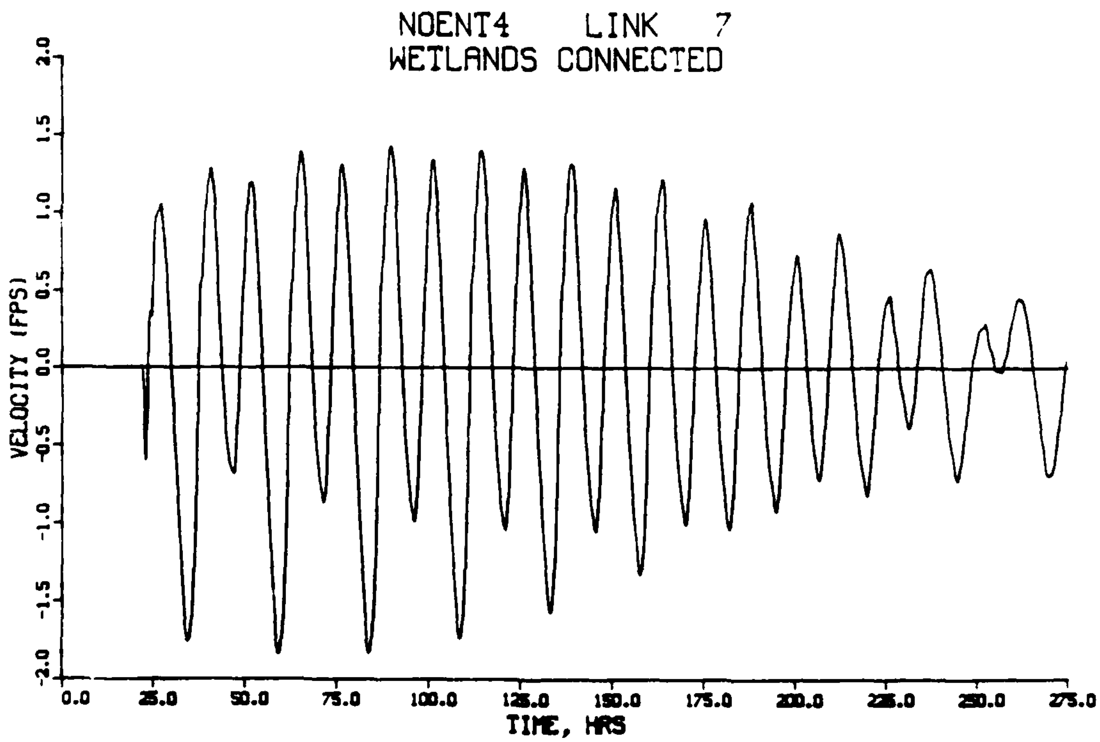


Figure N4. Average channel velocities in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

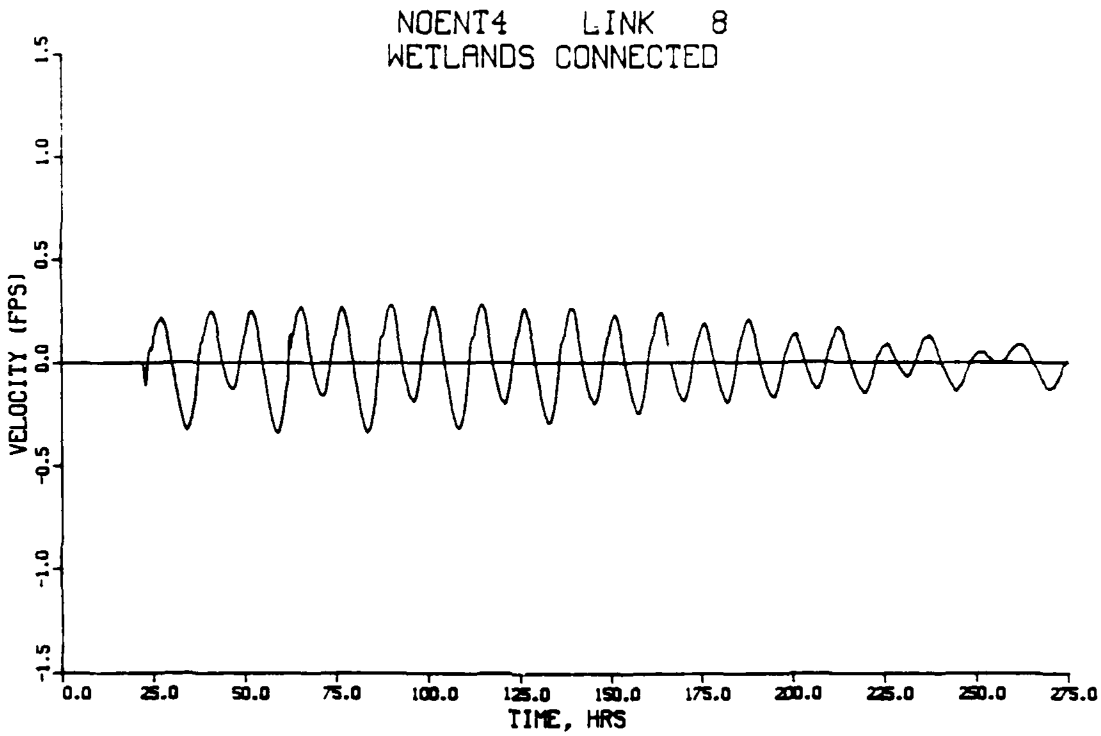


Figure N5. Average channel velocities in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

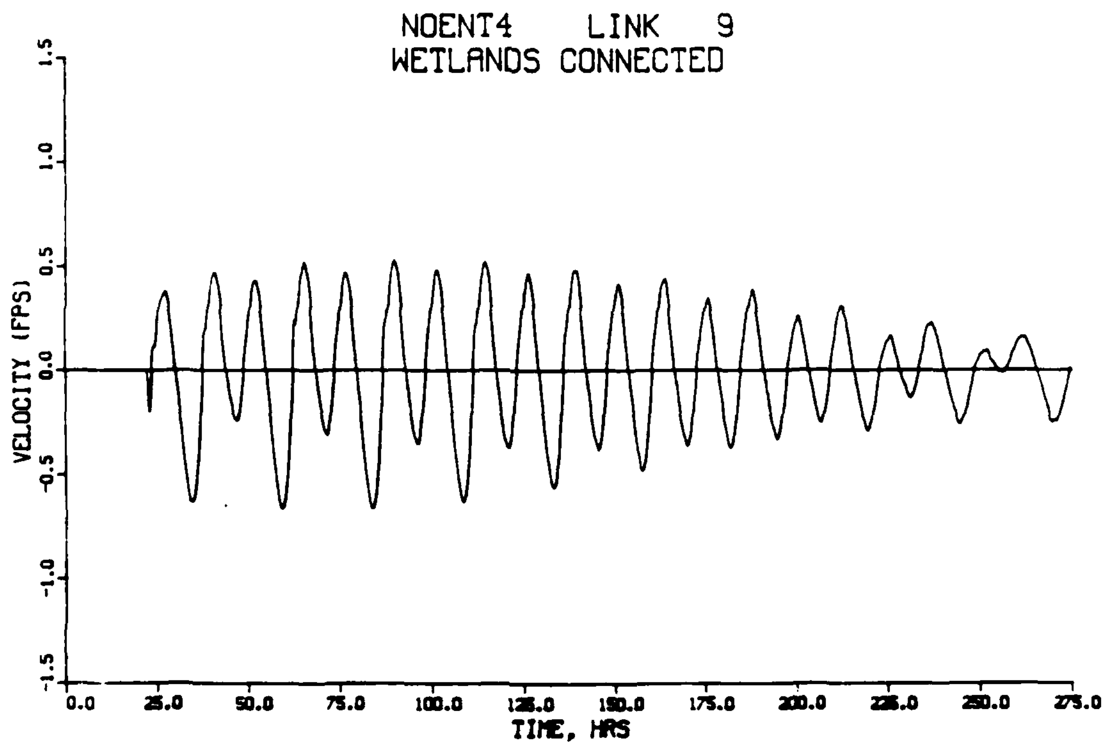


Figure N6. Average channel velocities in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

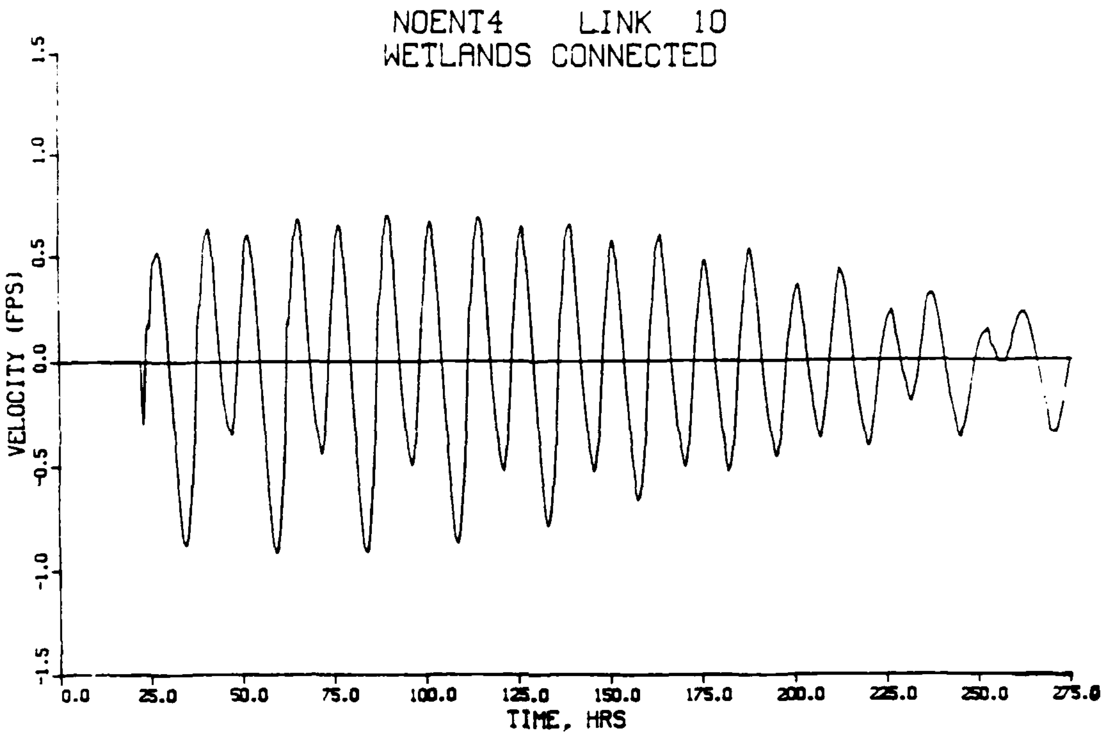


Figure N7. Average channel velocities in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

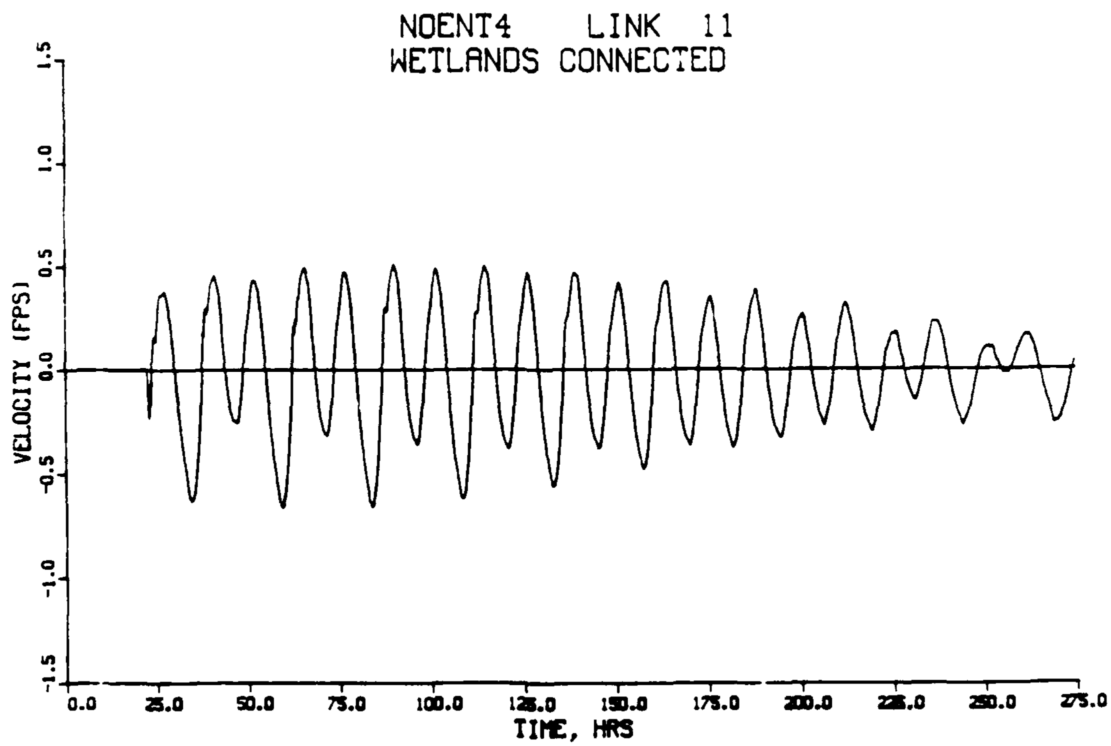


Figure N8. Average channel velocities in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

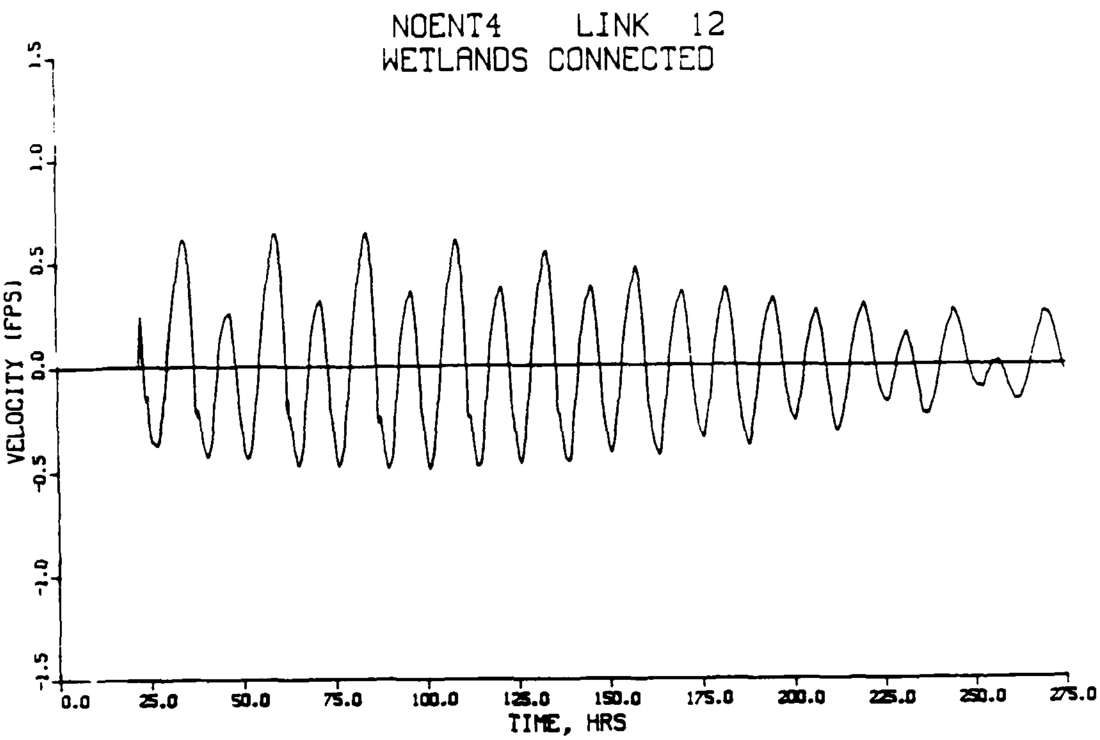


Figure N9. Average channel velocities in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

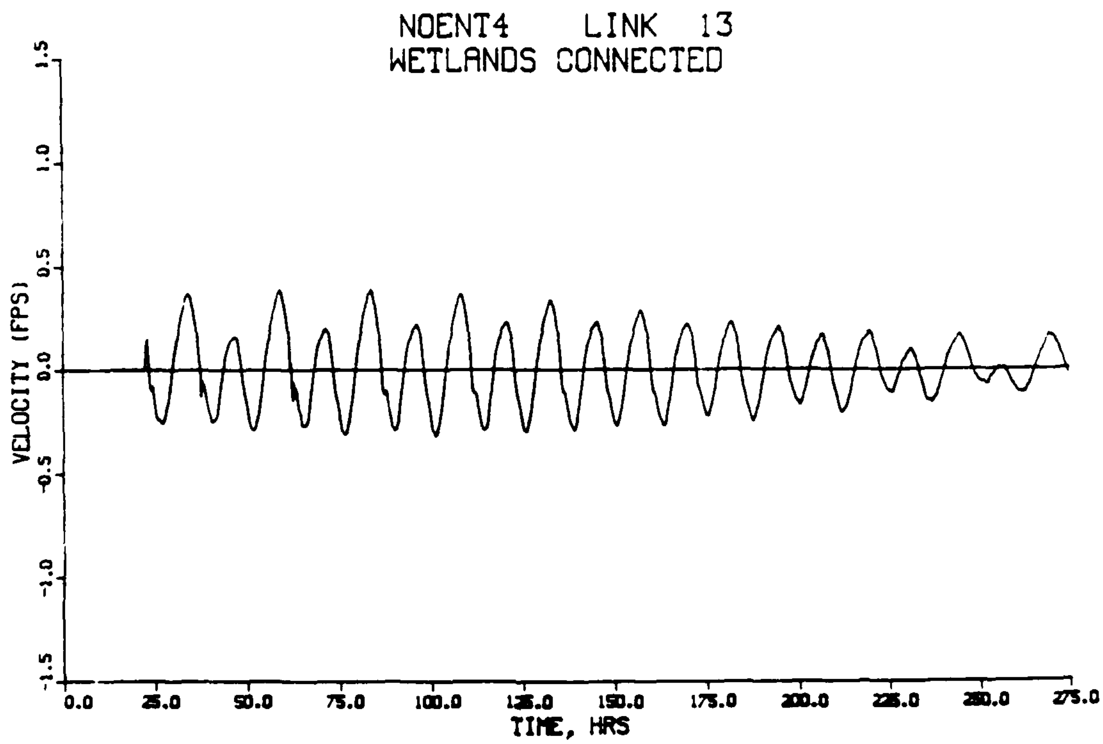


Figure N10. Average channel velocities in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

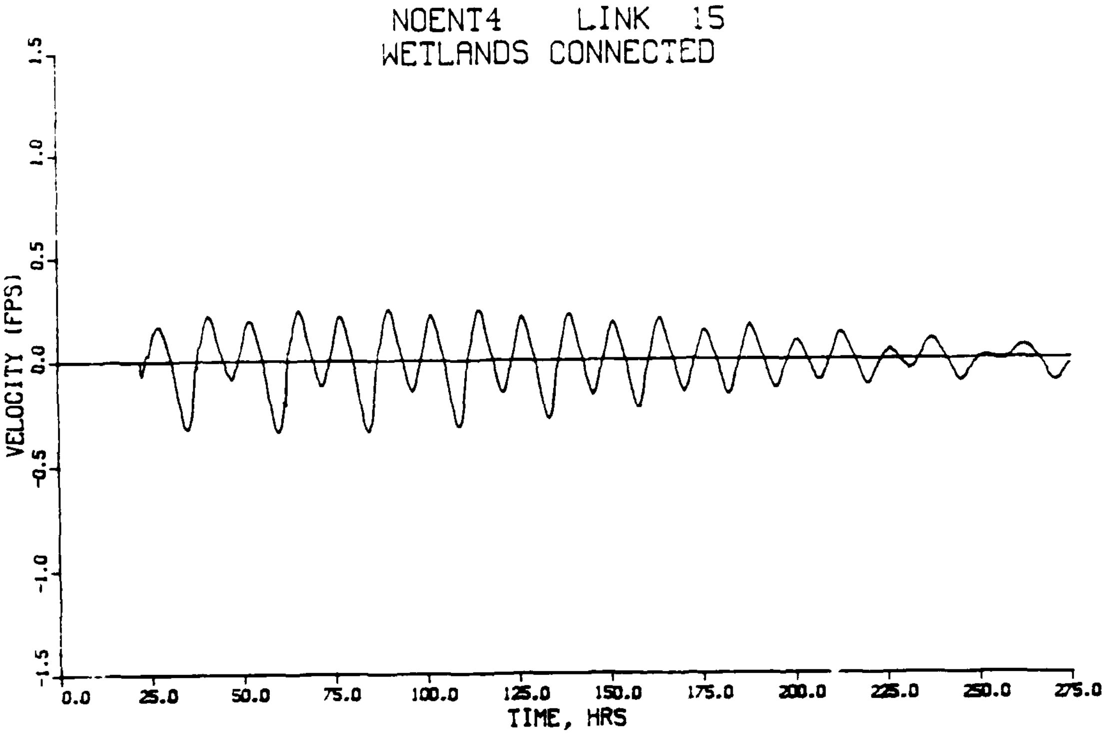


Figure N11. Average channel velocities in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

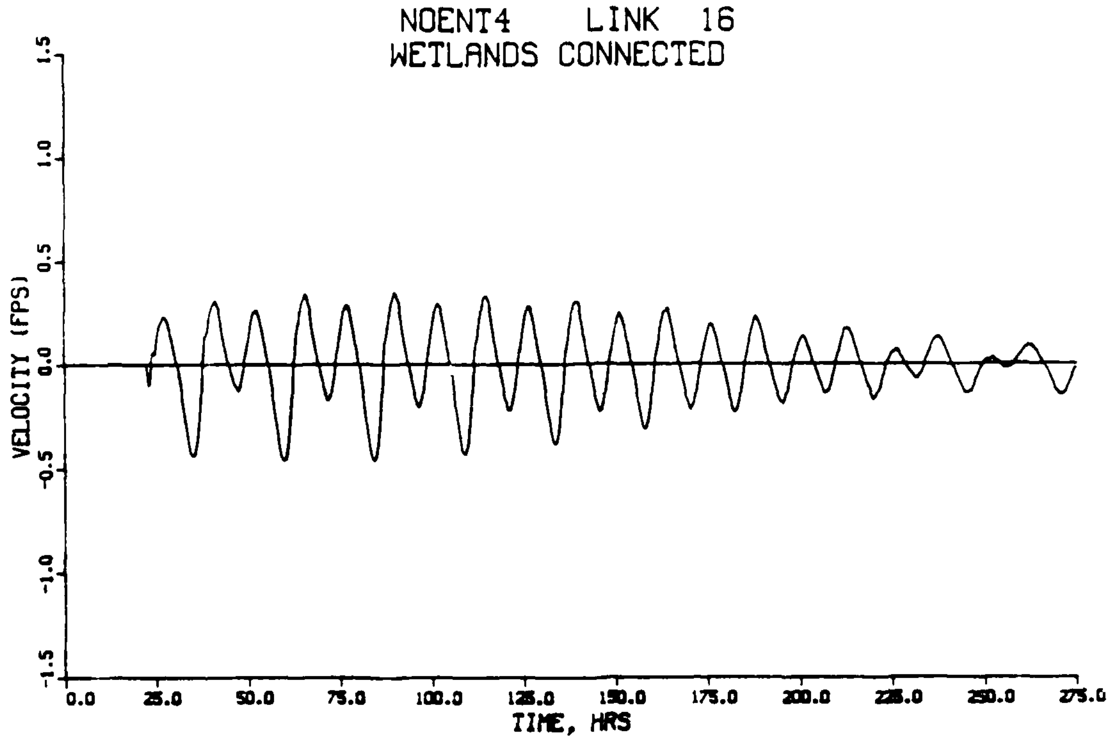


Figure N12. Average channel velocities in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

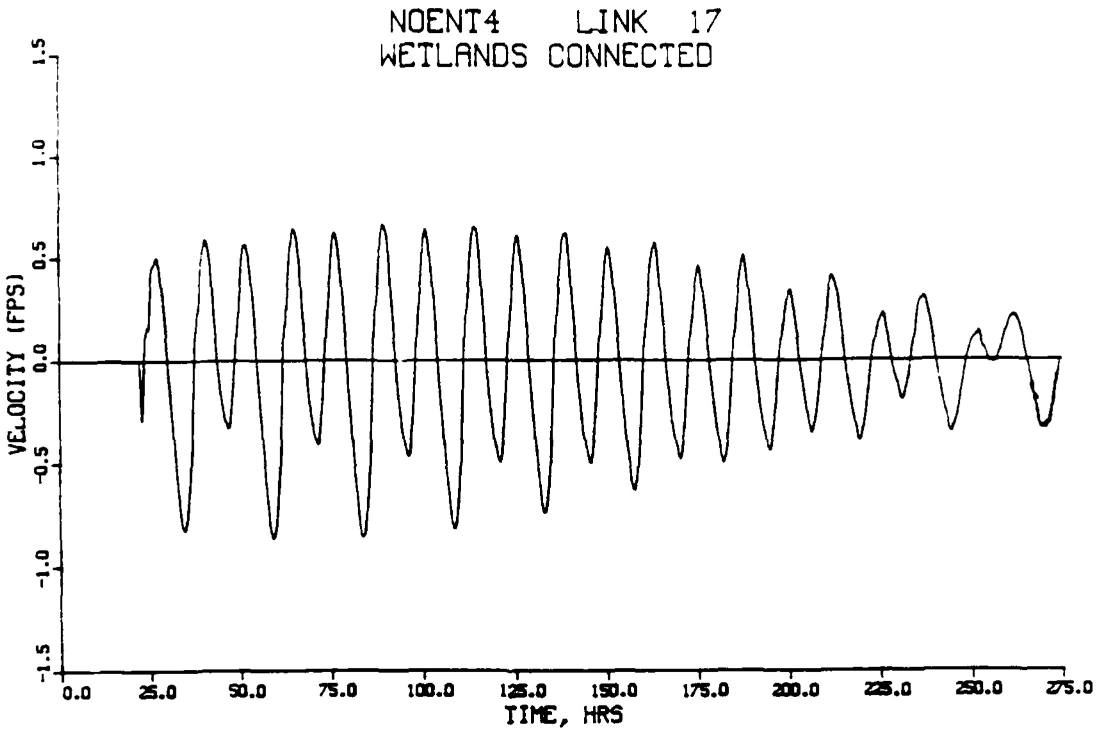


Figure N13. Average channel velocities in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

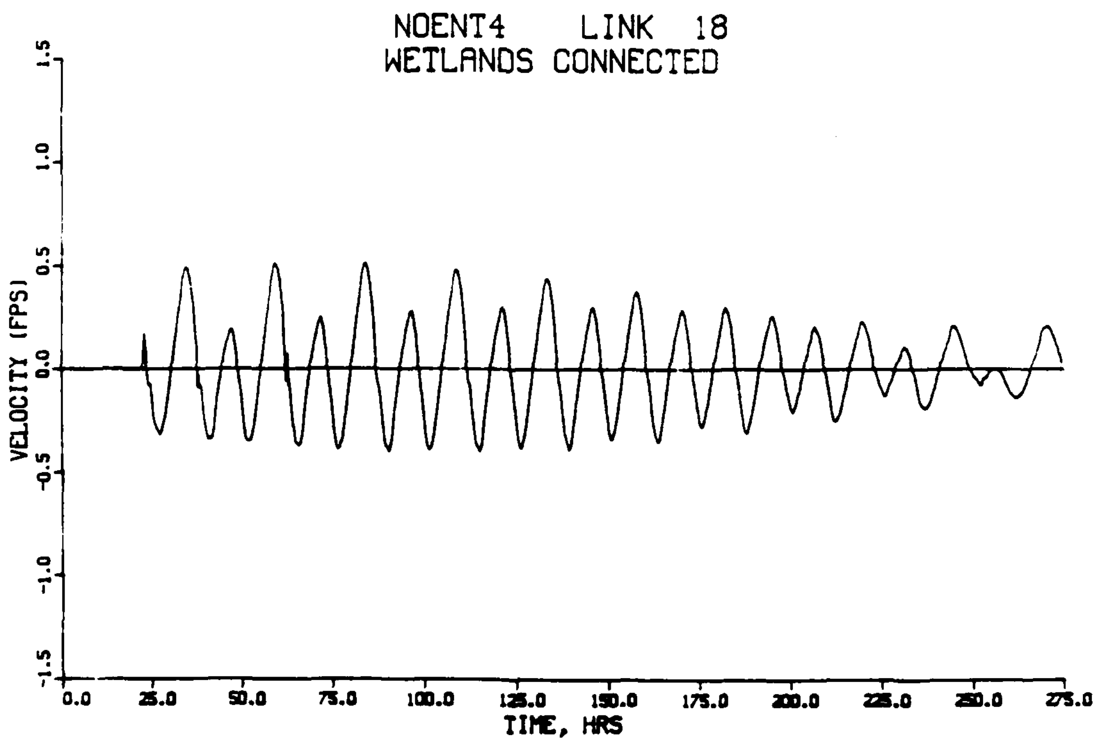


Figure N14. Average channel velocities in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

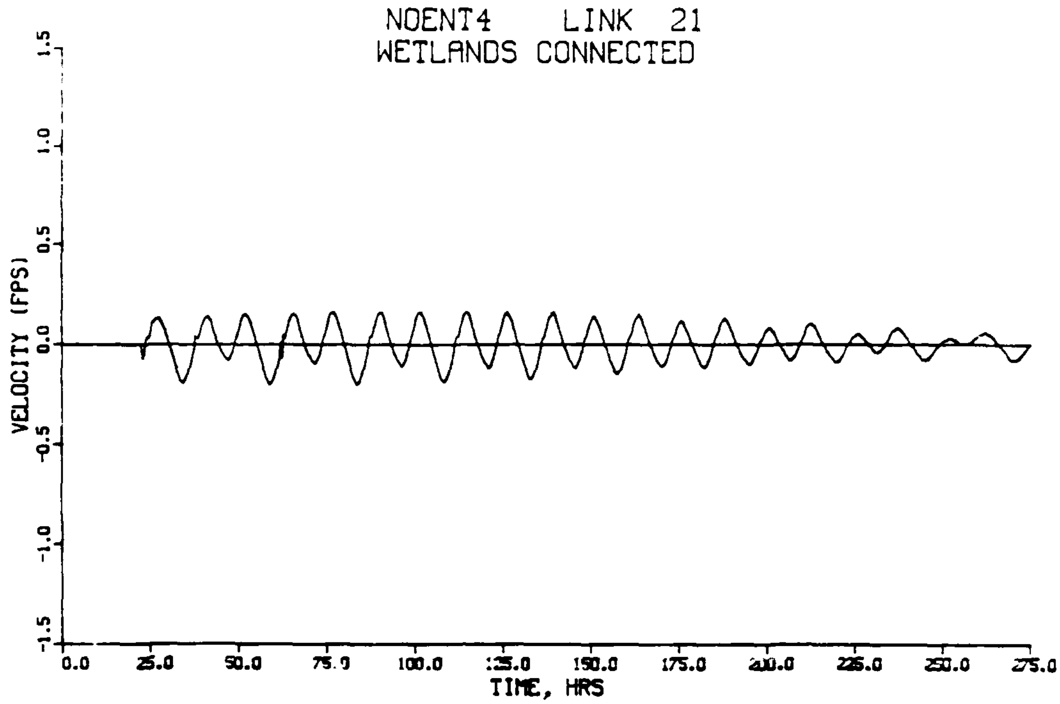


Figure N15. Average channel velocities in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

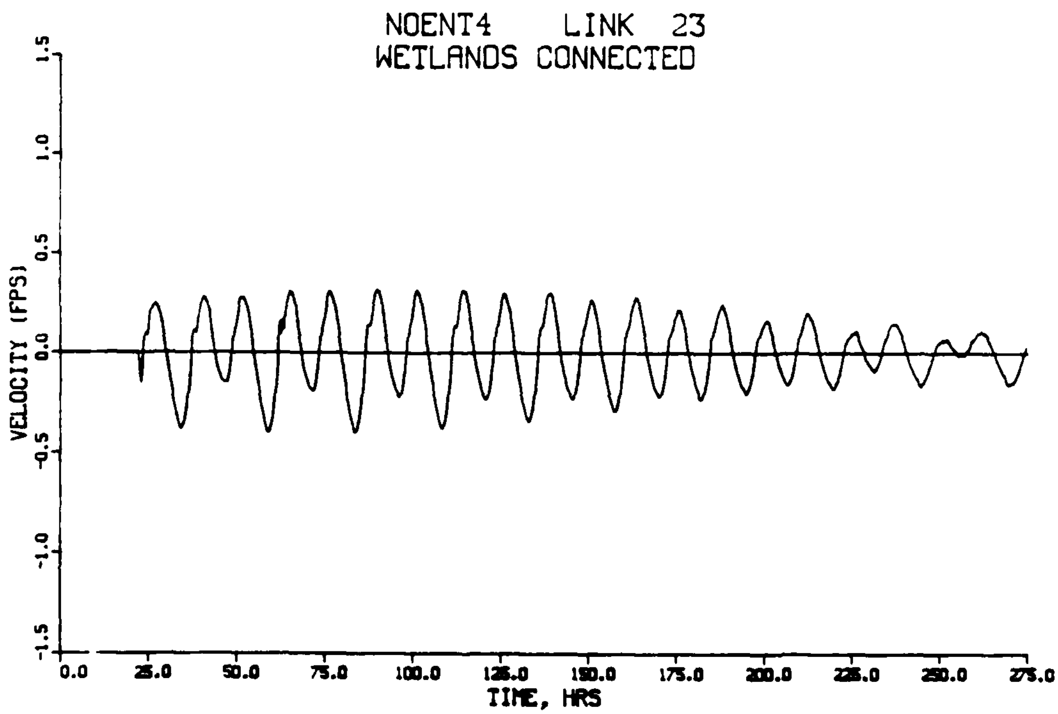


Figure N16. Average channel velocities in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

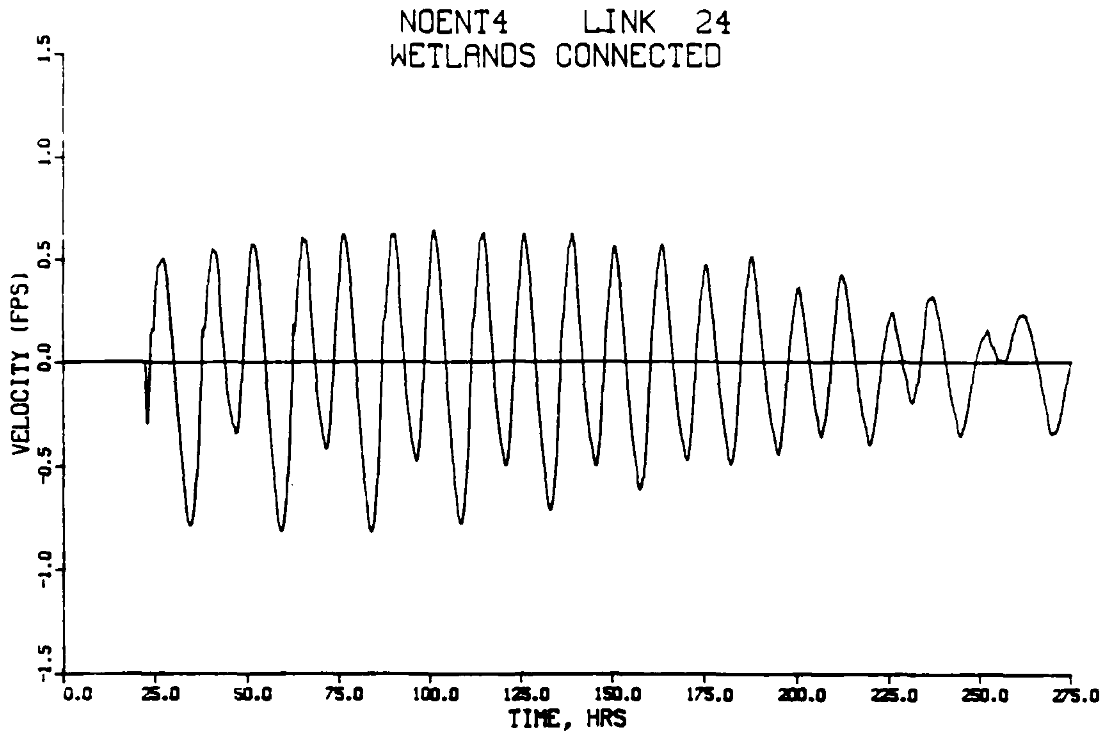


Figure N17. Average channel velocities in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

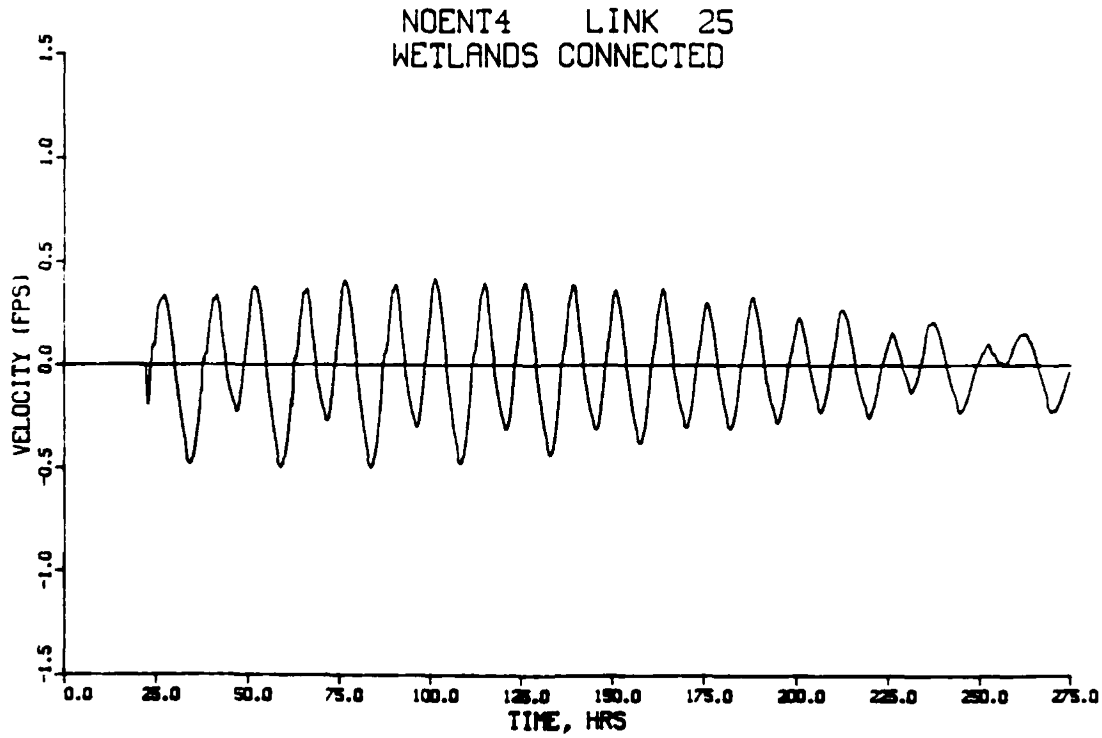


Figure N18. Average channel velocities in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

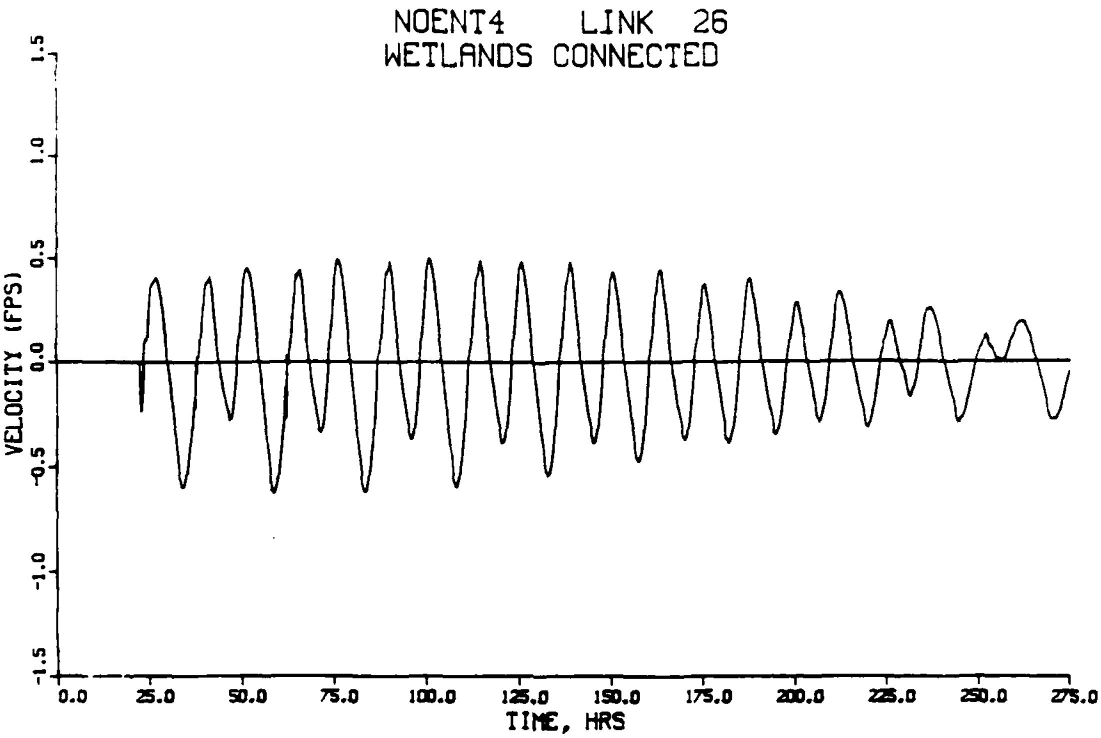


Figure N19. Average channel velocities in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

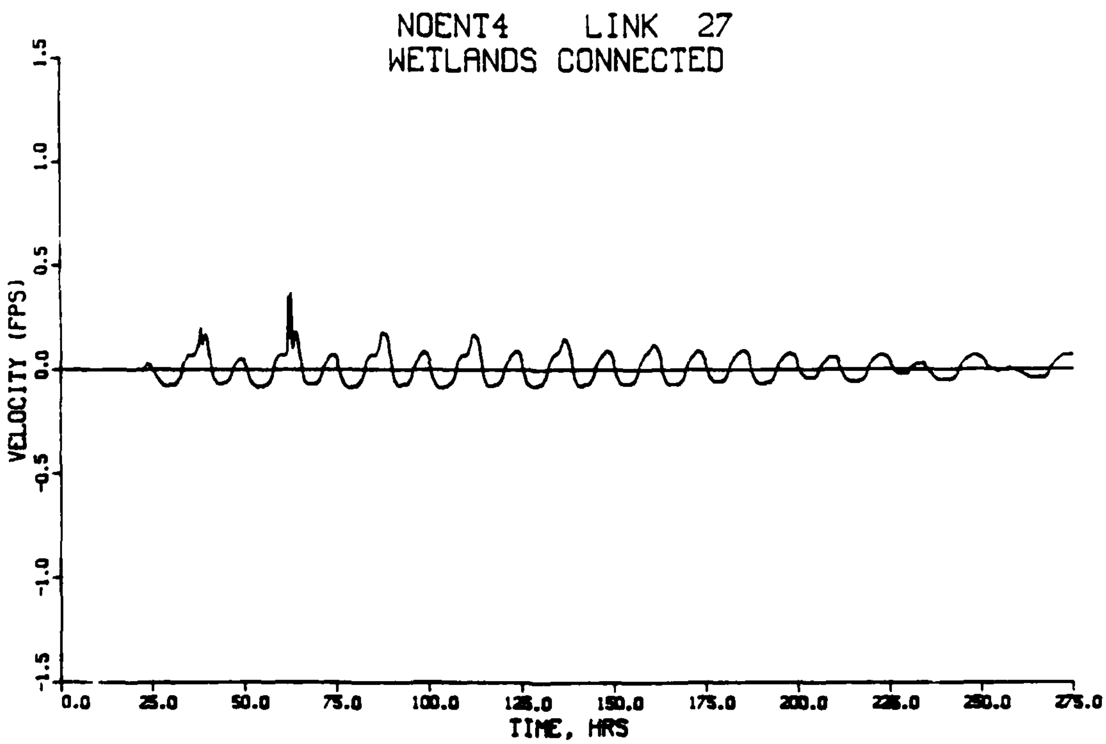


Figure N20. Average channel velocities in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

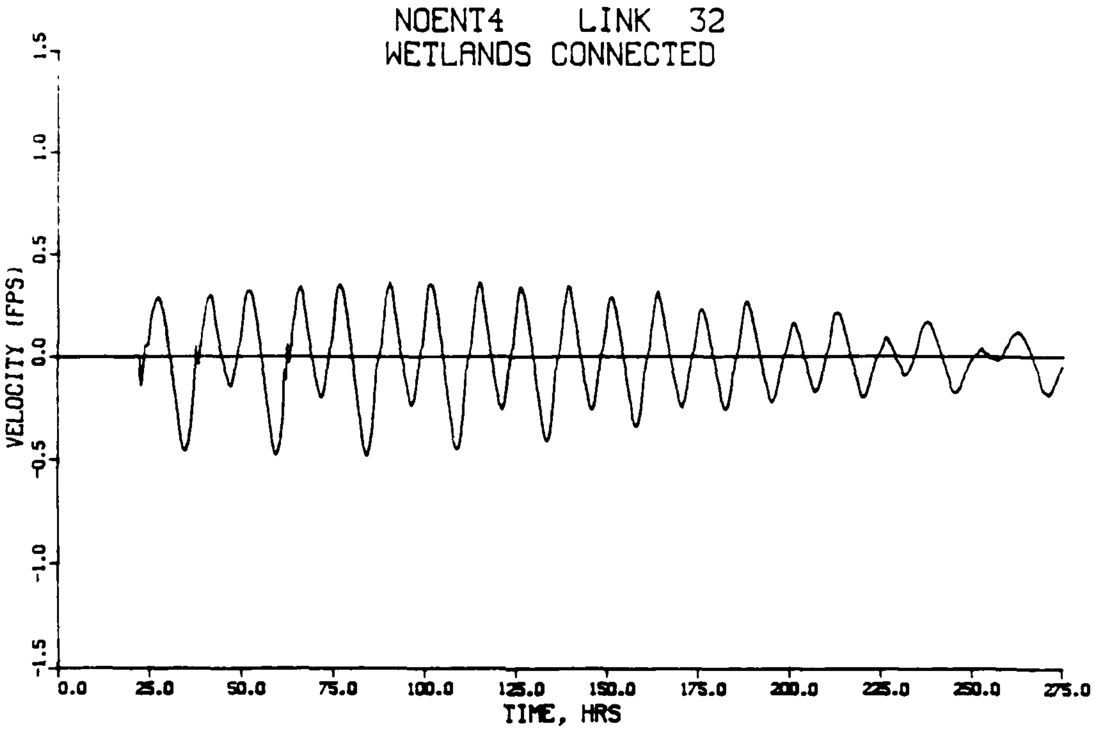


Figure N21. Average channel velocities in Huntington Harbour under non-navigable entrance closed, by-pass connector to marina conditions

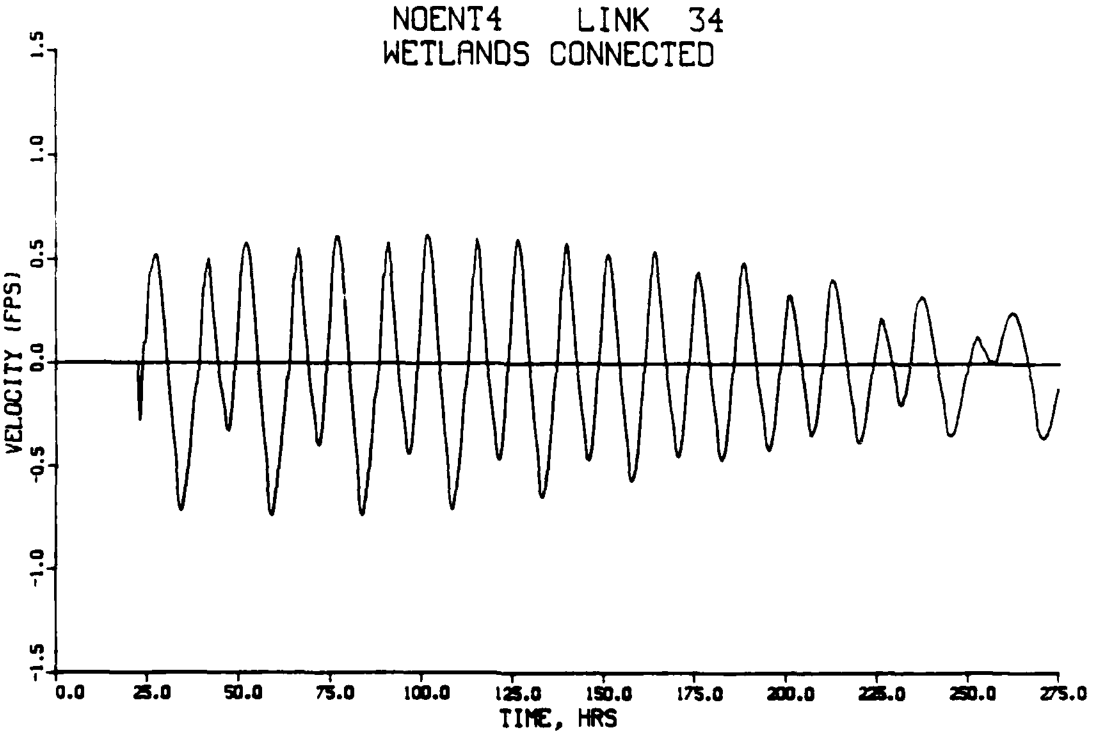


Figure N22. Average channel velocities at previous Warner Avenue under non-navigable entrance closed, by-pass connector to marina conditions

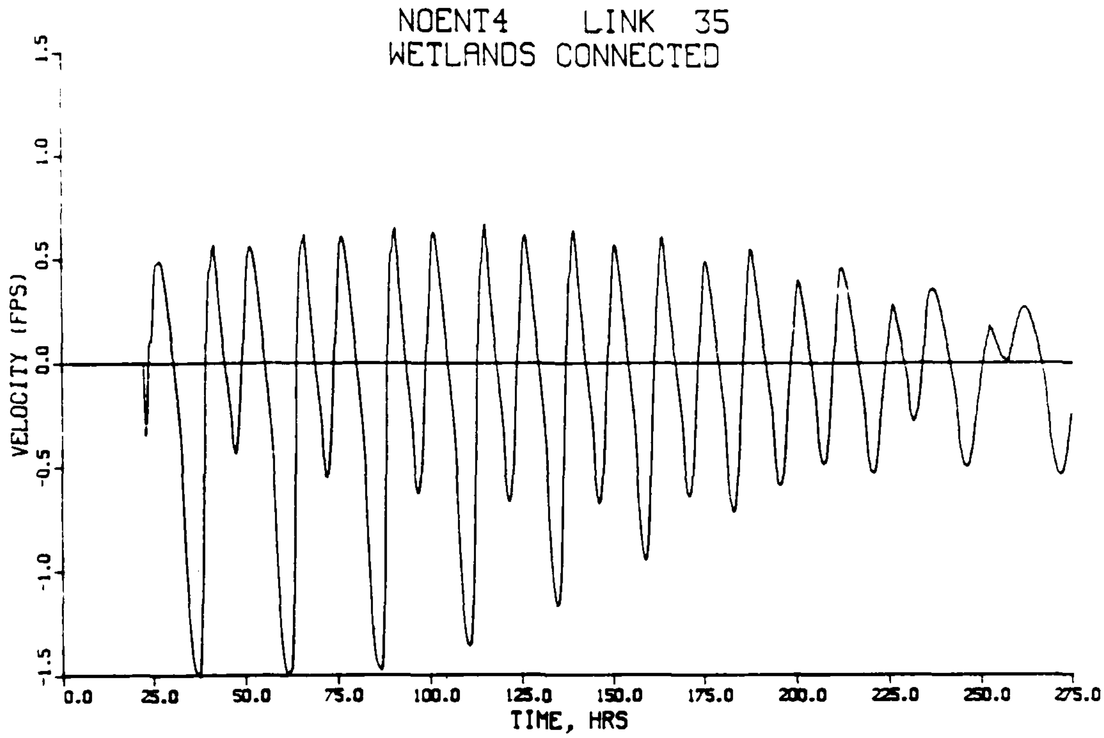


Figure N23. Average channel velocities in Outer Bolsa Bay under non-navigable entrance closed, by-pass connector to marina conditions

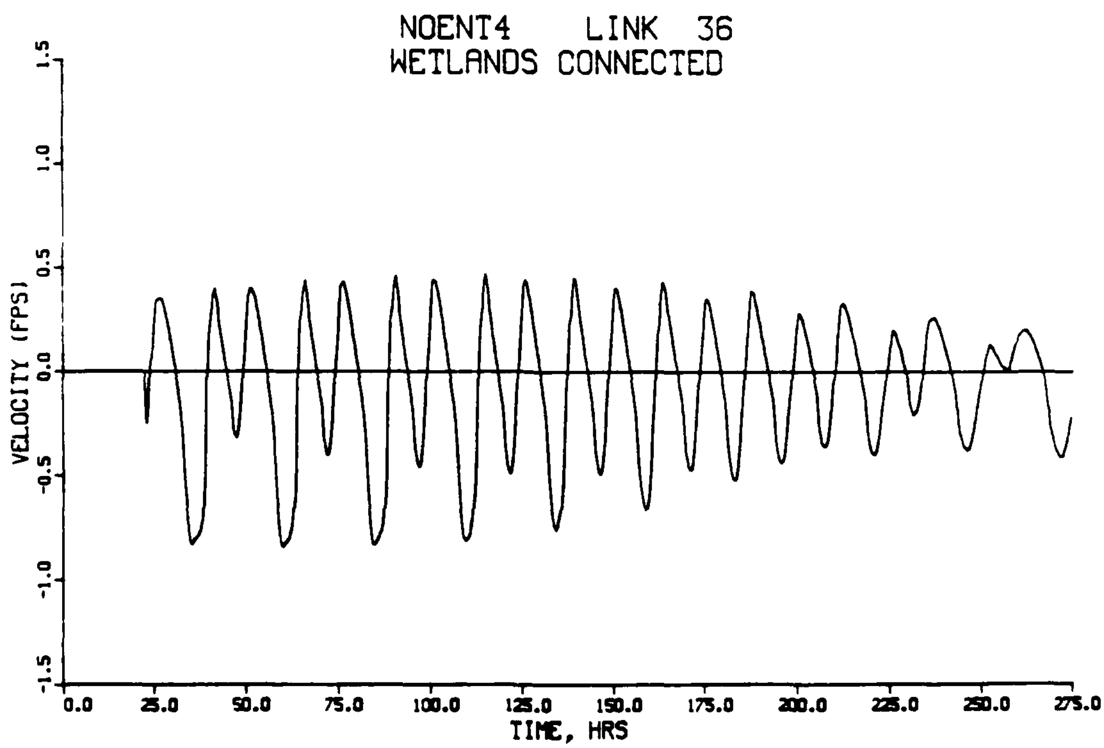


Figure N24. Average channel velocities in Outer Bolsa Bay under non-navigable entrance closed, by-pass connector to marina conditions

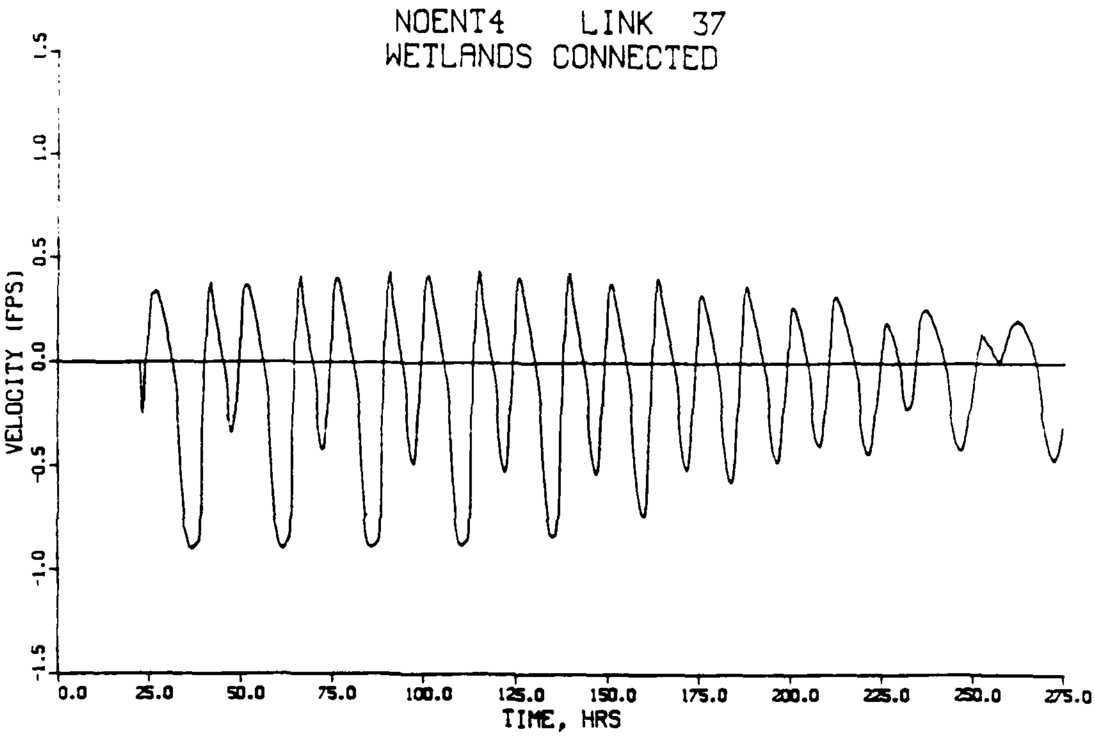


Figure N25. Average channel velocities in Outer Bolsa Bay under non-navigable entrance closed, by-pass connector to marina conditions

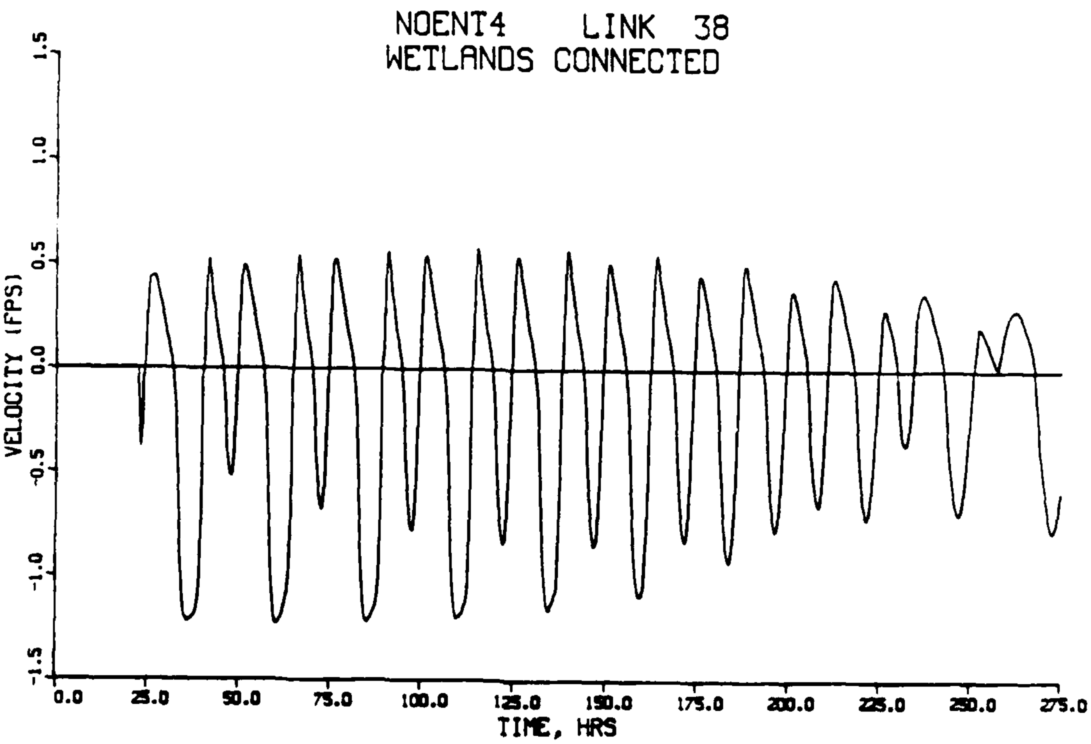


Figure N26. Average channel velocities in Outer Bolsa Bay under non-navigable entrance closed, by-pass connector to marina conditions

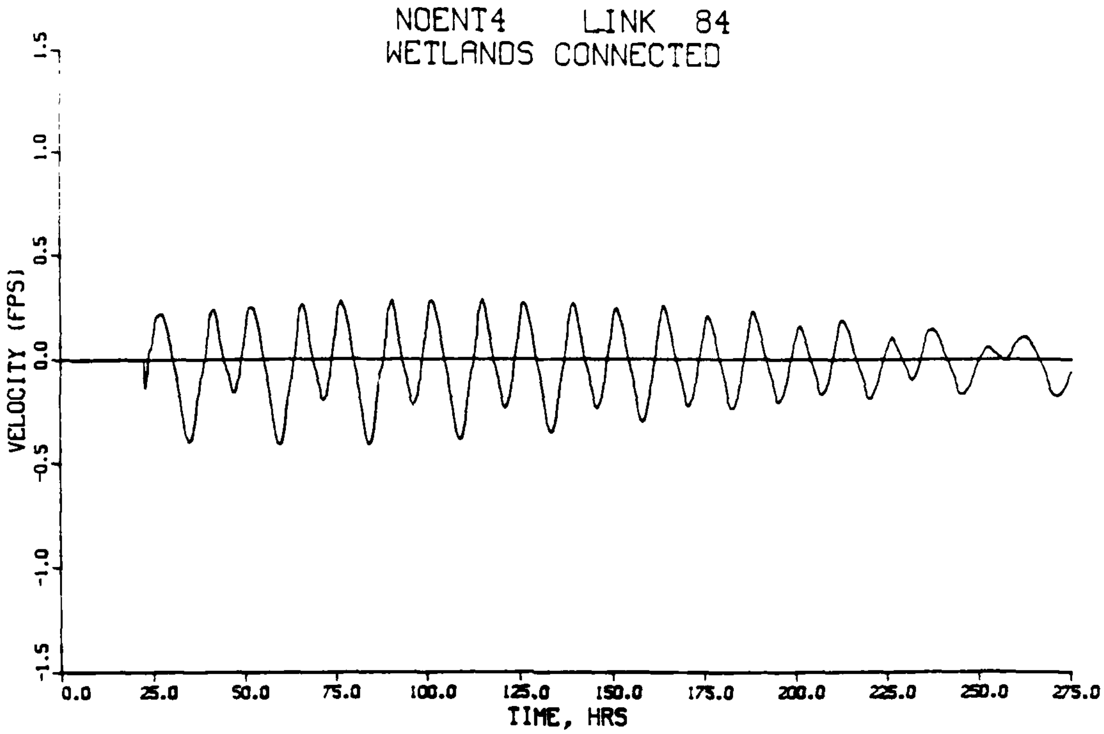


Figure N27. Average channel velocities in channel to proposed marina under non-navigable entrance closed, by-pass connector to marina conditions

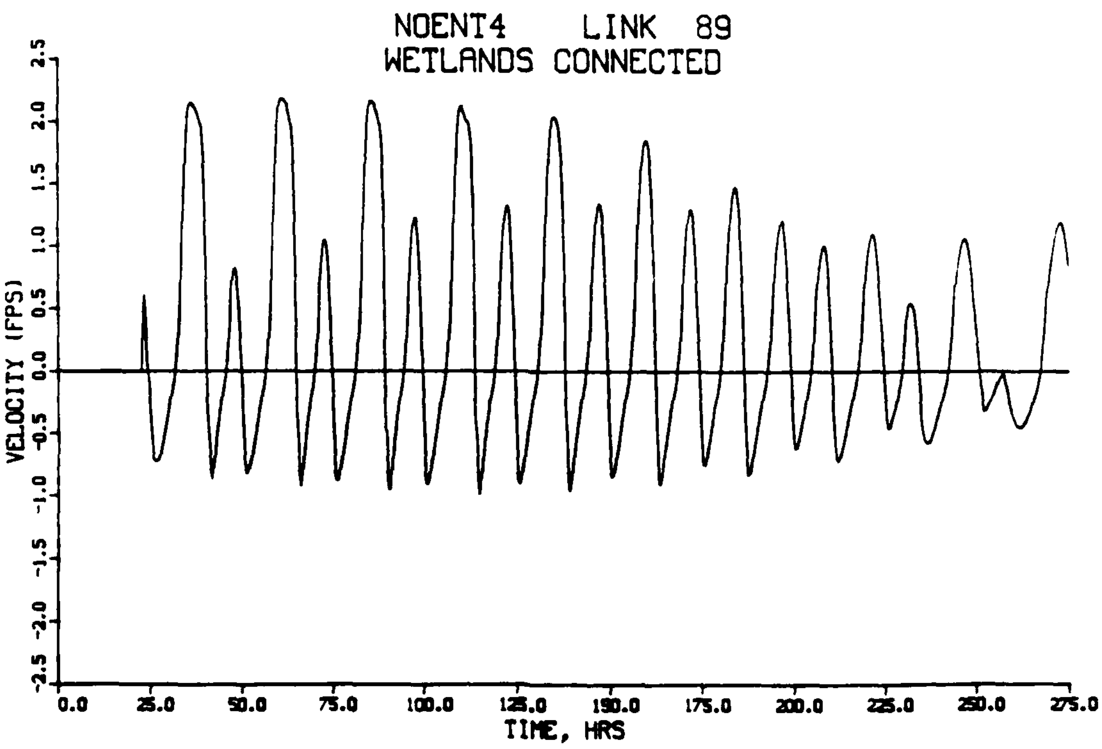


Figure N28. Average channel velocities in by-pass connector channel under non-navigable entrance closed, by-pass connector to marina conditions

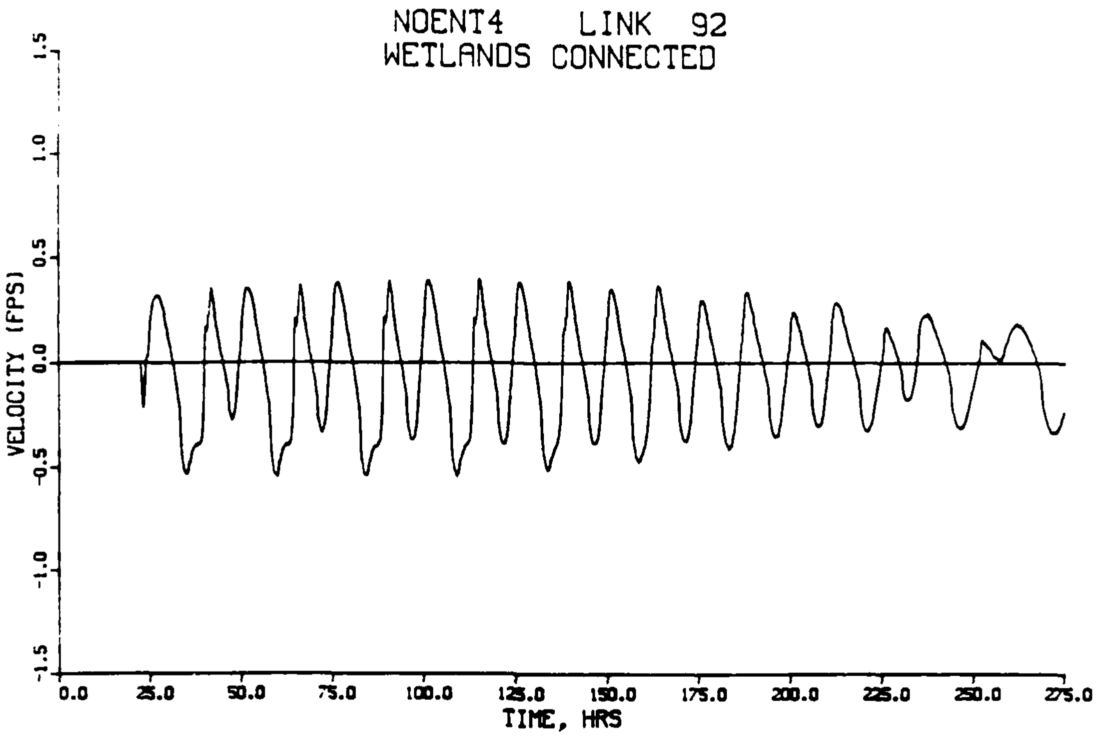


Figure N29. Average channel velocities EGG-WFCC under non-navigable entrance closed, by-pass connector to marina conditions

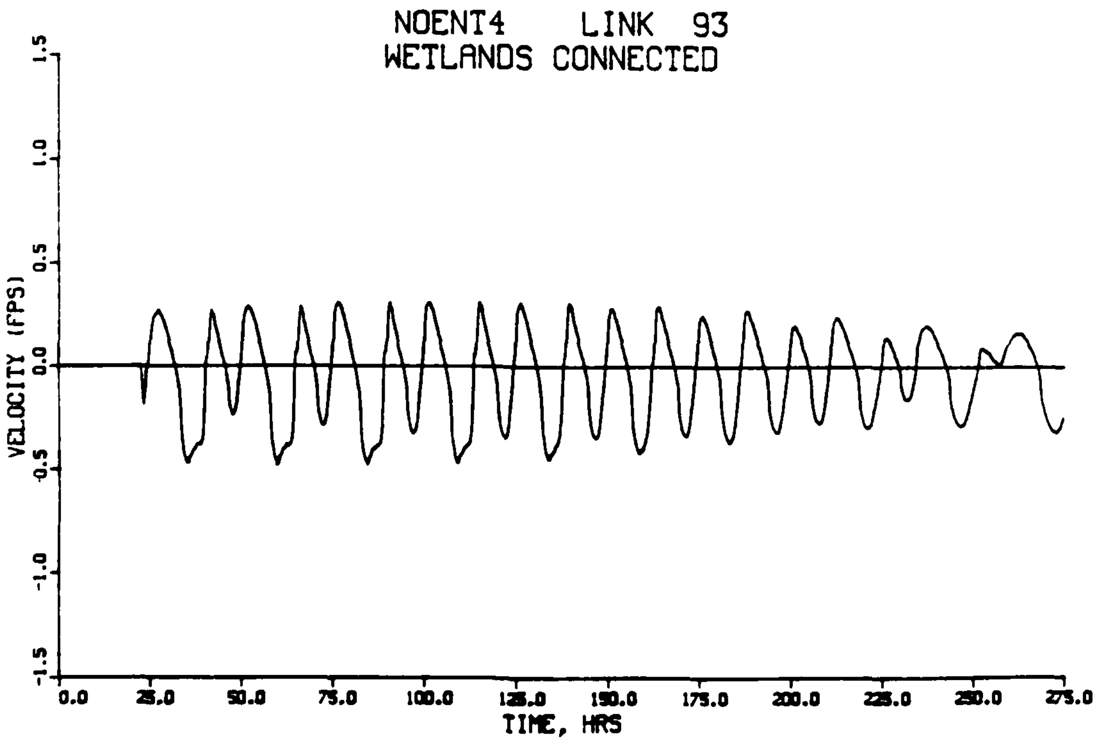


Figure N30. Average channel velocities EGG-WFCC under non-navigable entrance closed, by-pass connector to marina conditions

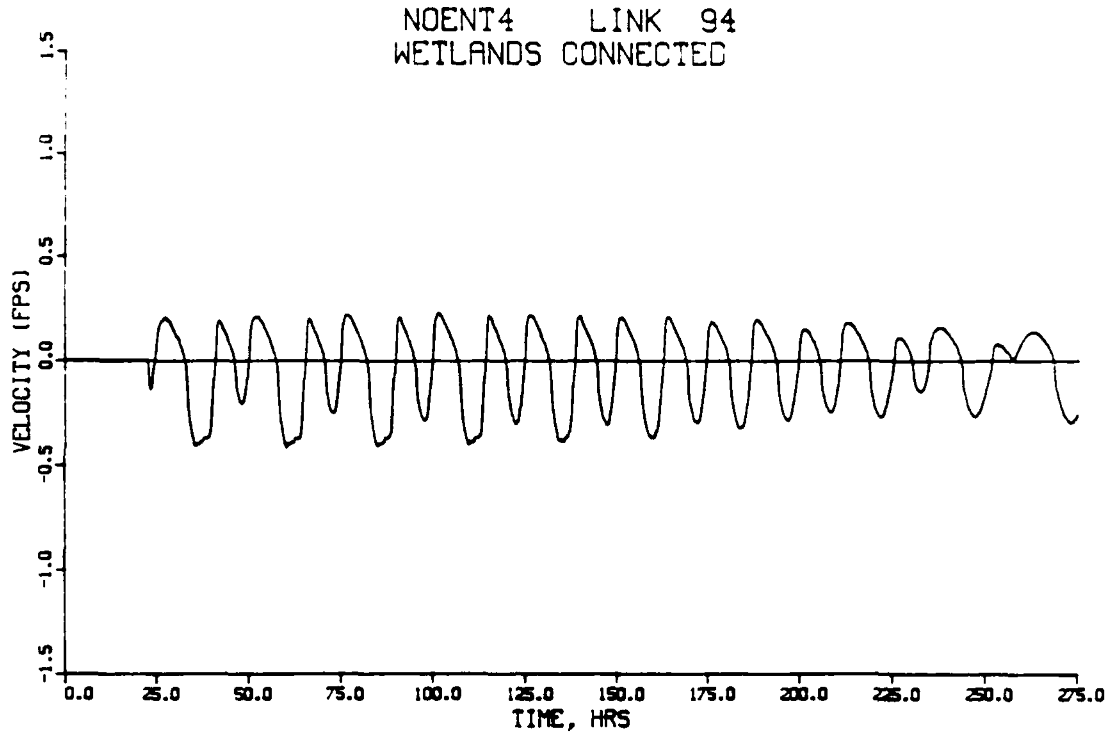


Figure N31. Average channel velocities EGG-WFCC under non-navigable entrance closed, by-pass connector to marina conditions

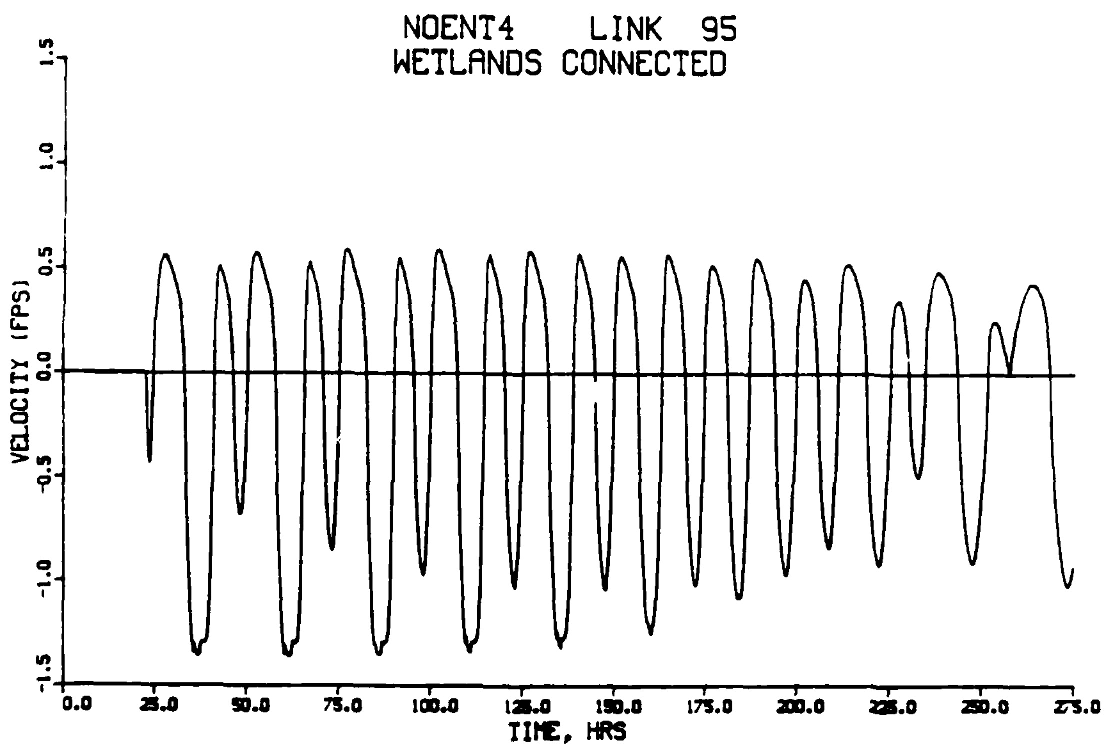


Figure N32. Average channel velocities in channel to muted wetlands under non-navigable entrance closed, by-pass connector to marina conditions

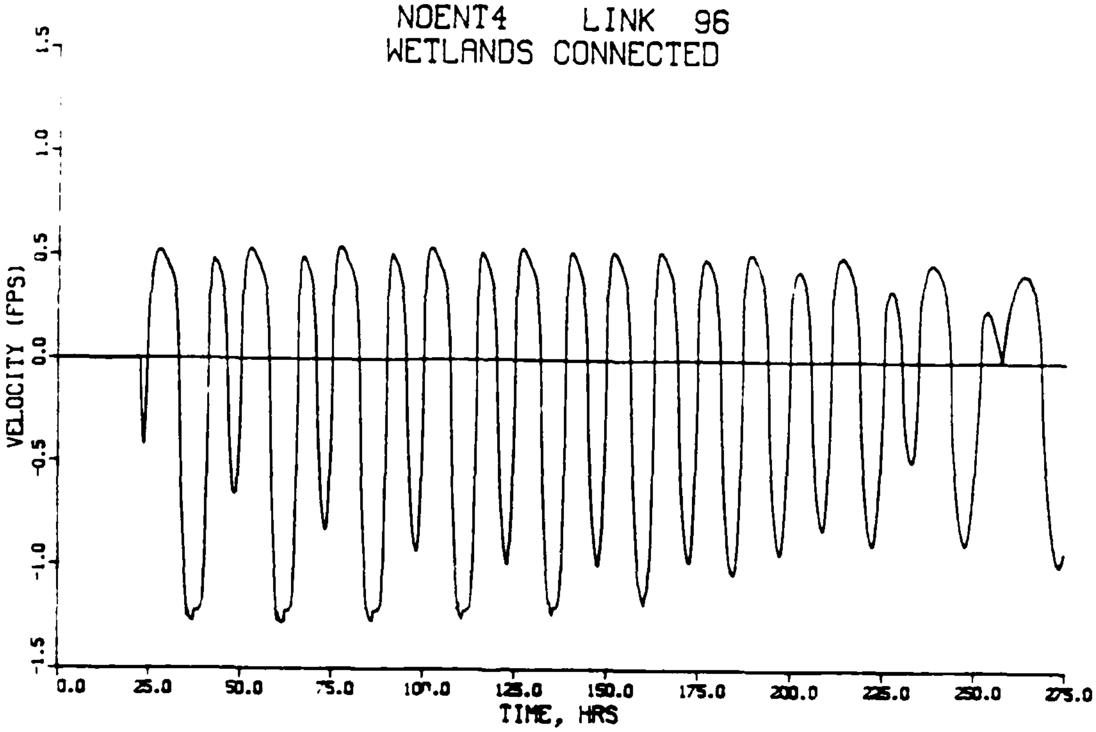


Figure N33. Average channel velocities in channel to muted wetlands under non-navigable entrance closed, by-pass connector to marina conditions

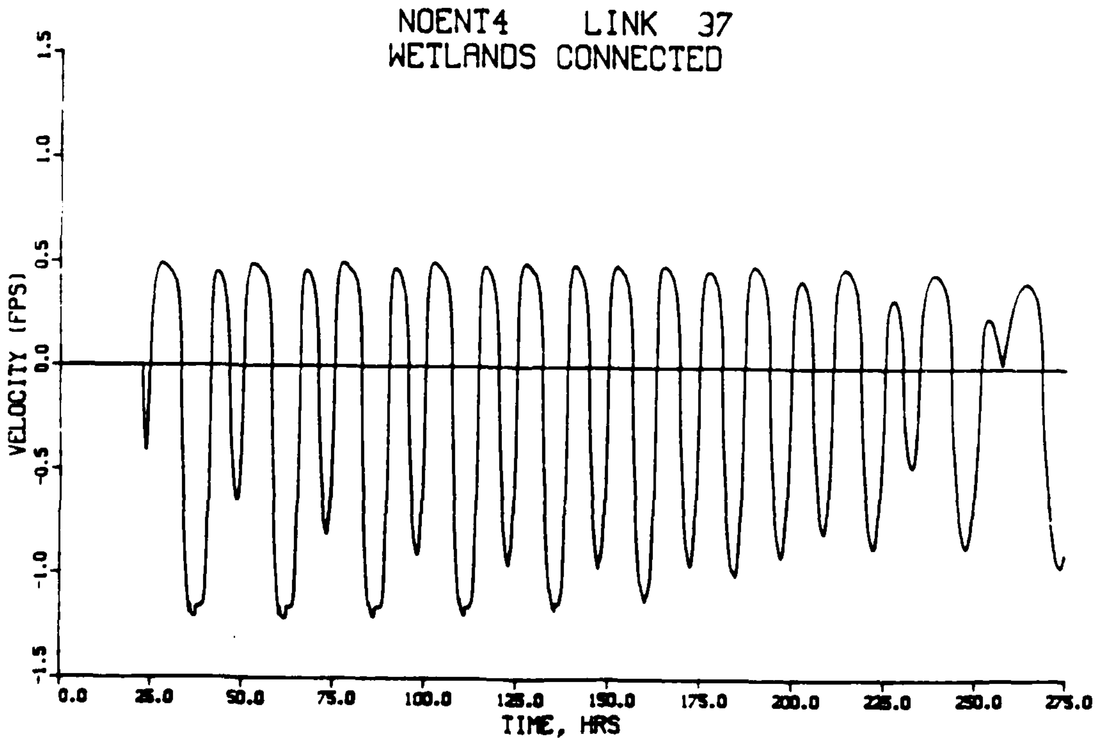


Figure N34. Average channel velocities in channel to muted wetlands under non-navigable entrance closed, by-pass connector to marina conditions

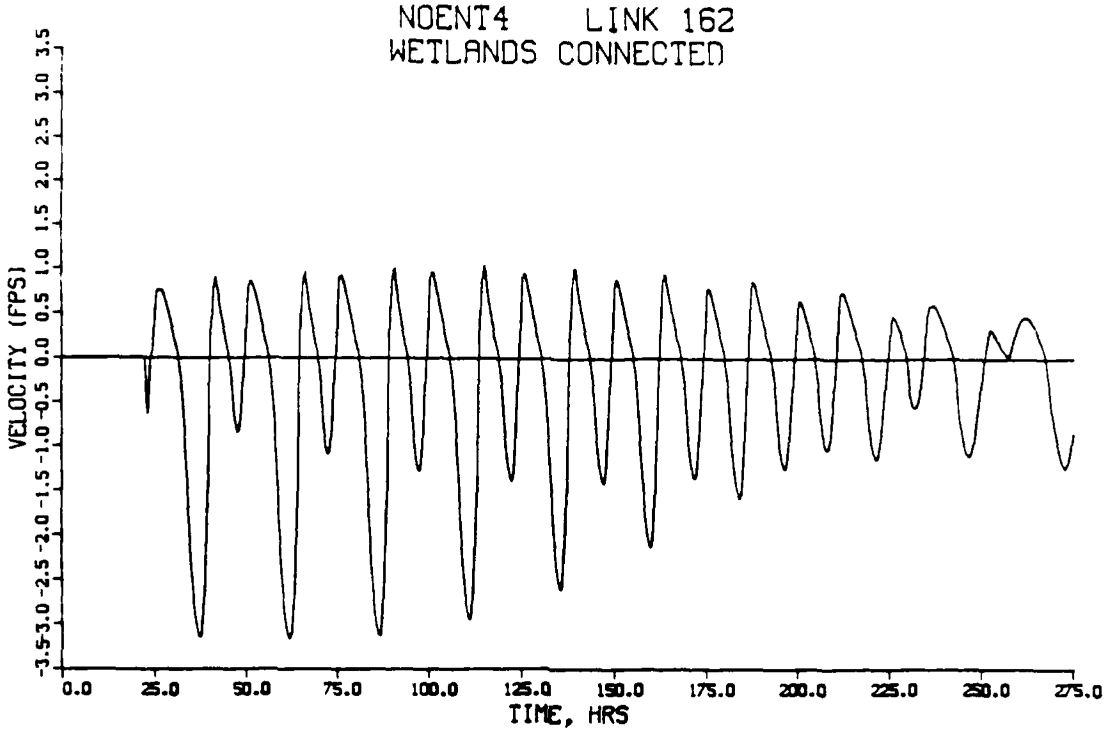


Figure N35. Average channel velocities in by-pass connector channel under non-navigable entrance closed, by-pass connector to marina conditions

APPENDIX O:

EAST GARDEN GROVE-WINTERSBURG FLOOD CONTROL CHANNEL (EGG-WFCC) 100-YEAR FLOOD FLOW

WATER SURFACE ELEVATIONS

The locations of nodes on Figures O1 through O18 are shown on Figures 29, 66, and 83.

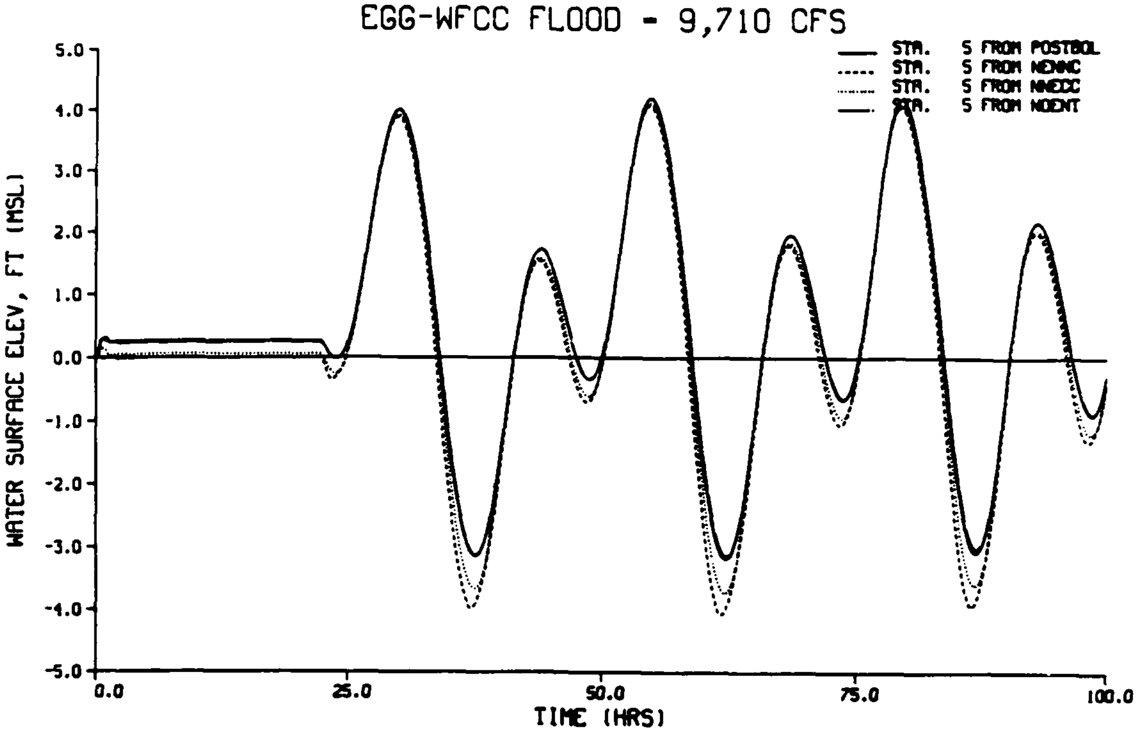


Figure 01. Water surface elevations in Huntington Harbour, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

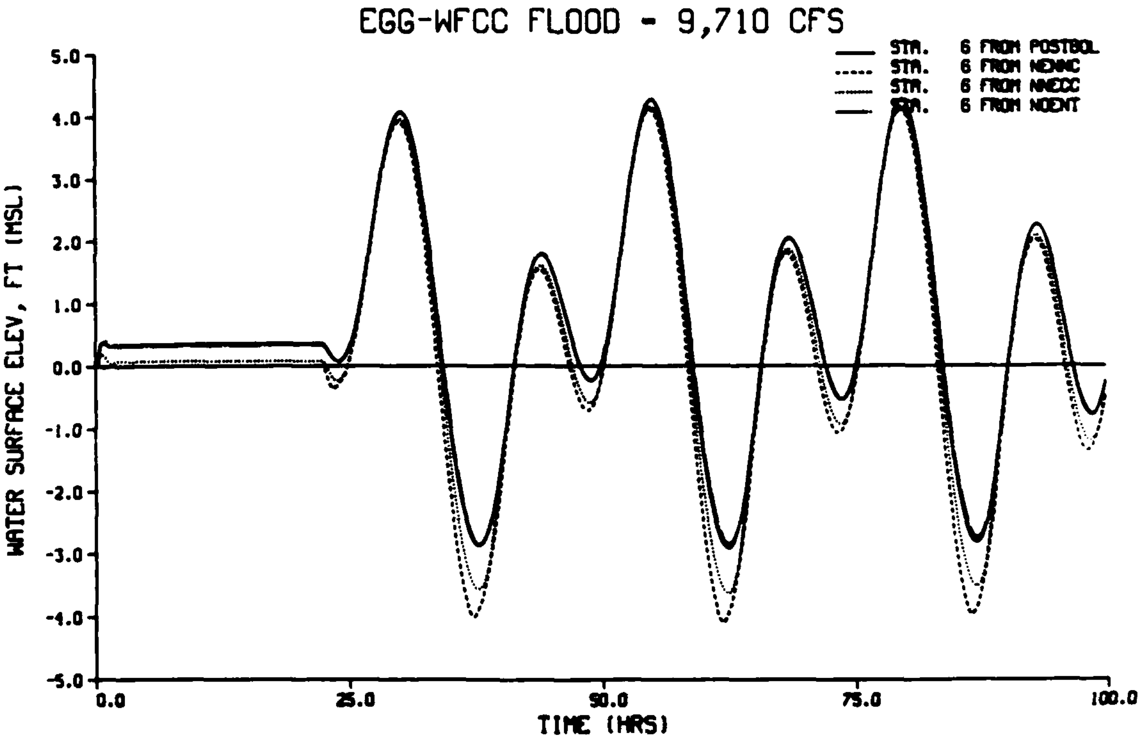


Figure 02. Water surface elevations in Huntington Harbour, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

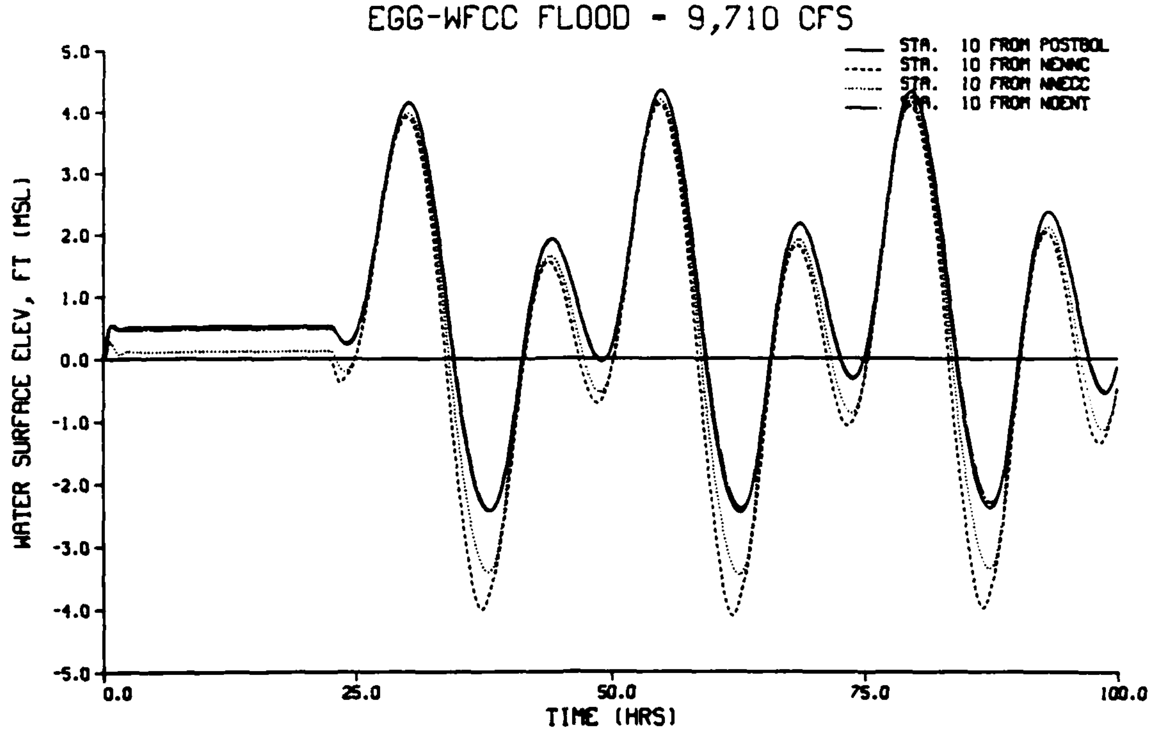


Figure 03. Water surface elevations in Huntington Harbour, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

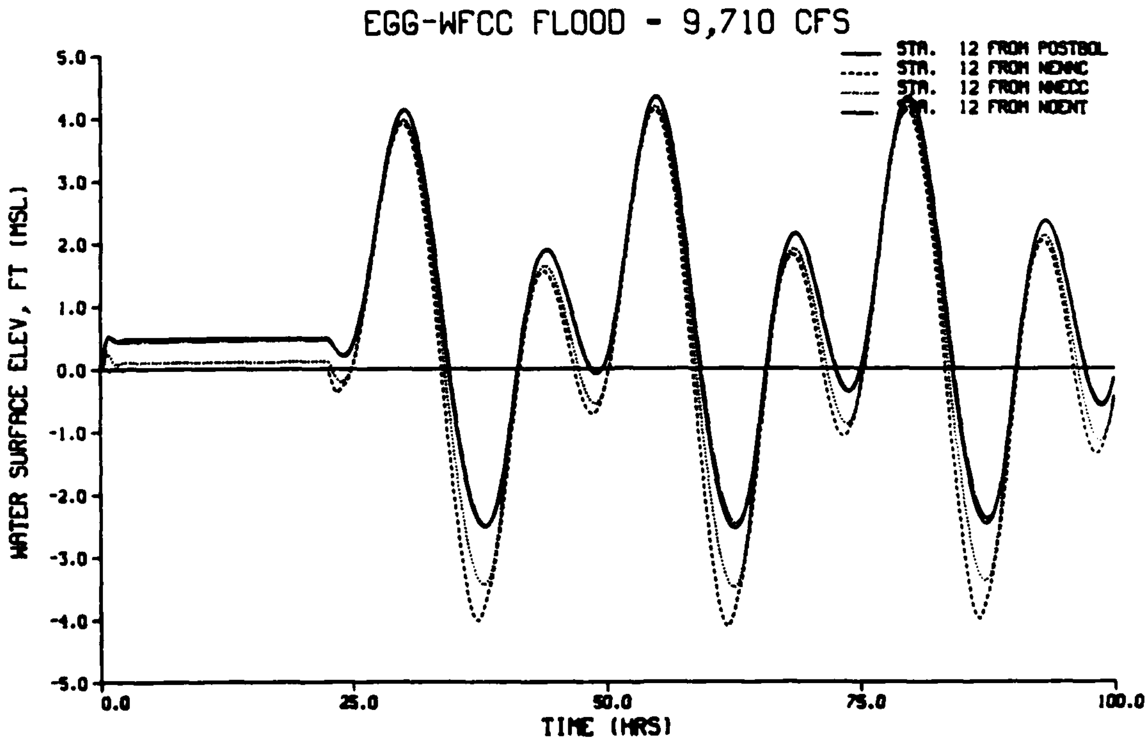


Figure 04. Water surface elevations in Huntington Harbour, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

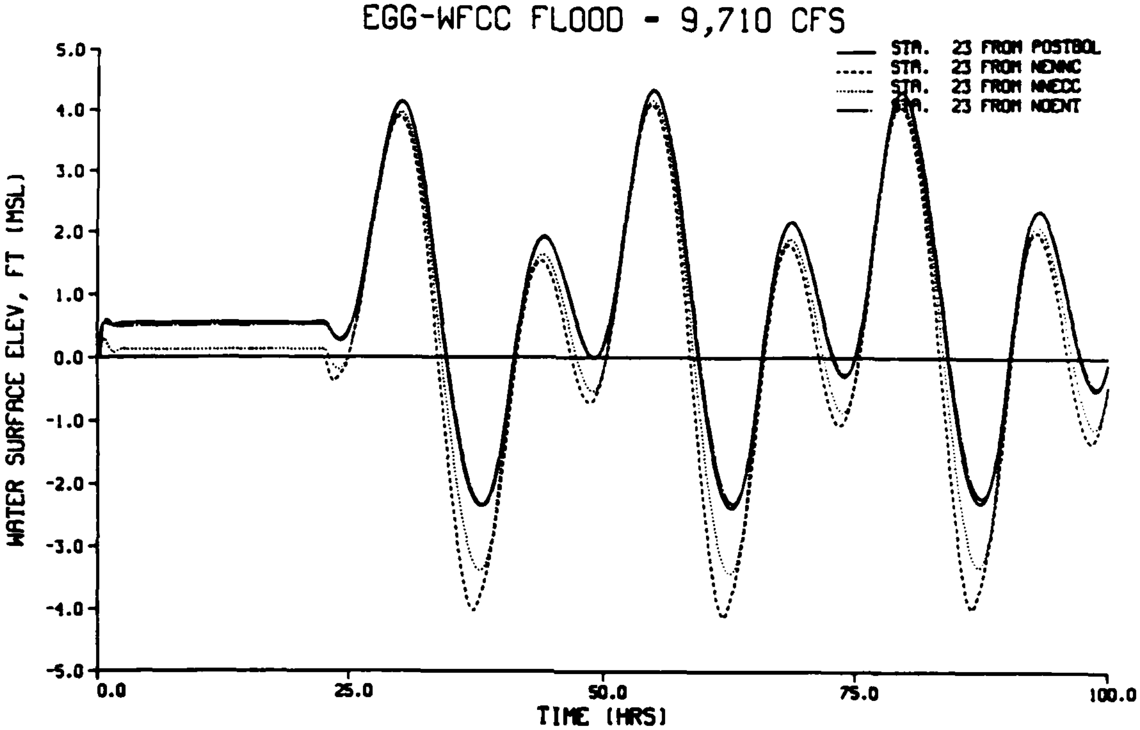


Figure 05. Water surface elevations in Huntington Harbour, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

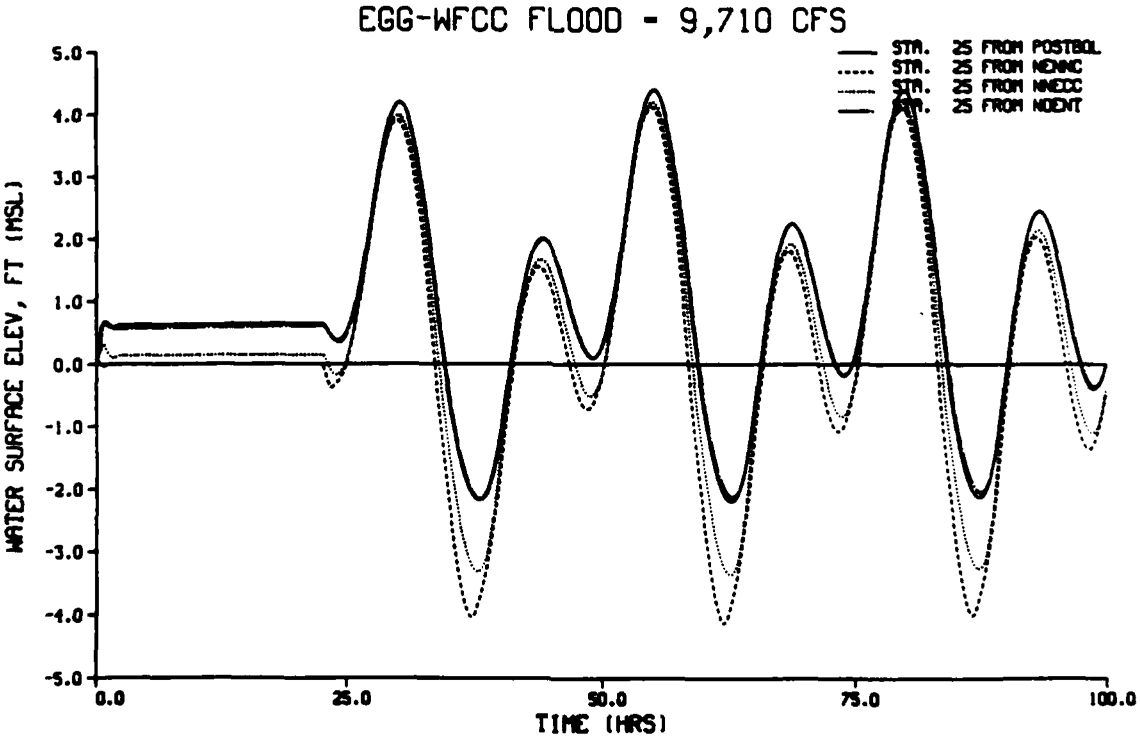


Figure 06. Water surface elevations in Huntington Harbour, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

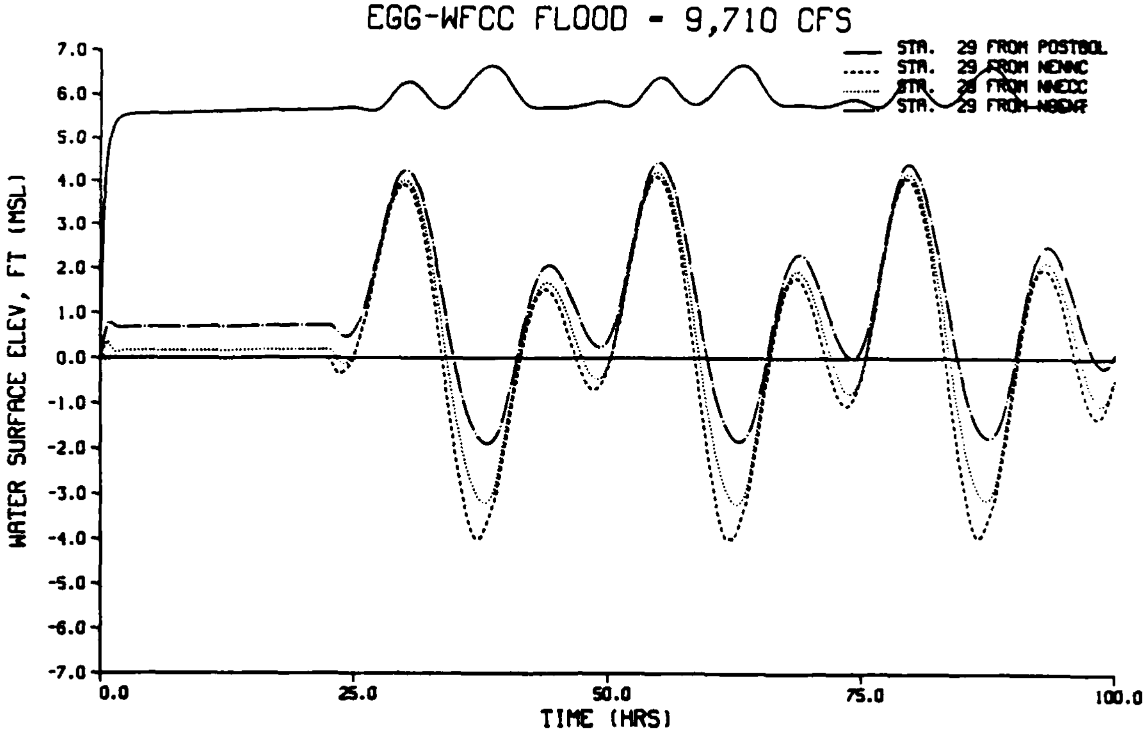


Figure 07. Water surface elevations in Outer Bolsa Bay, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

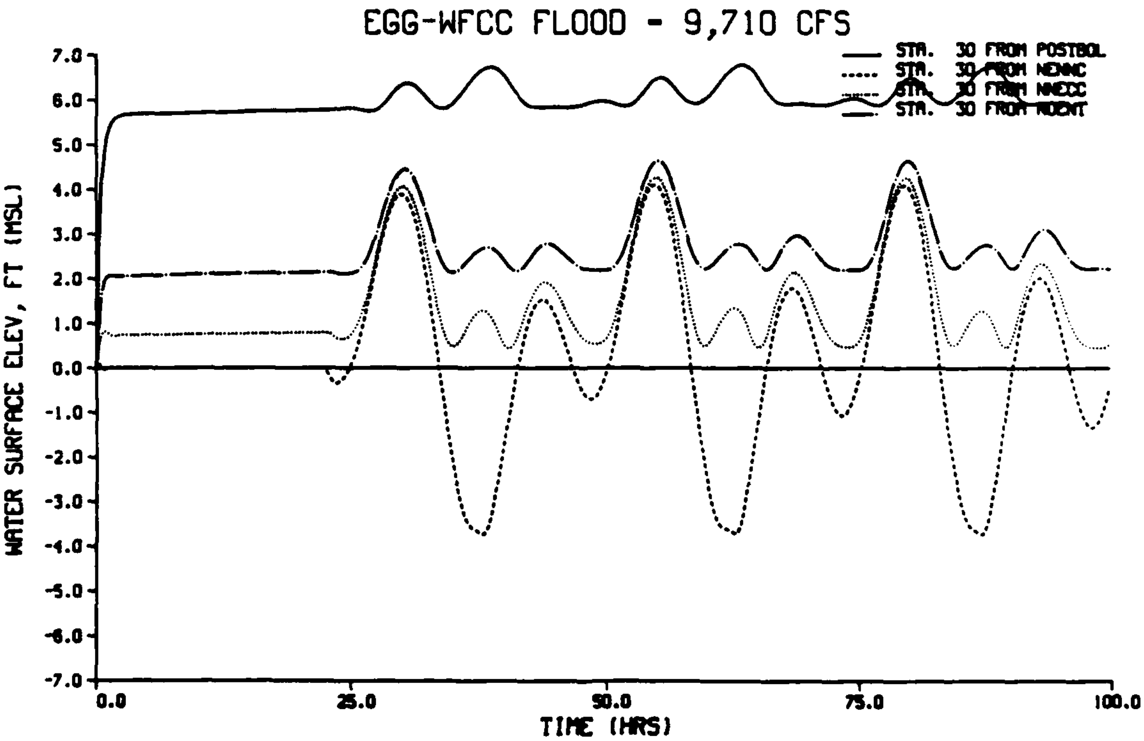


Figure 08. Water surface elevations in Outer Bolsa Bay, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

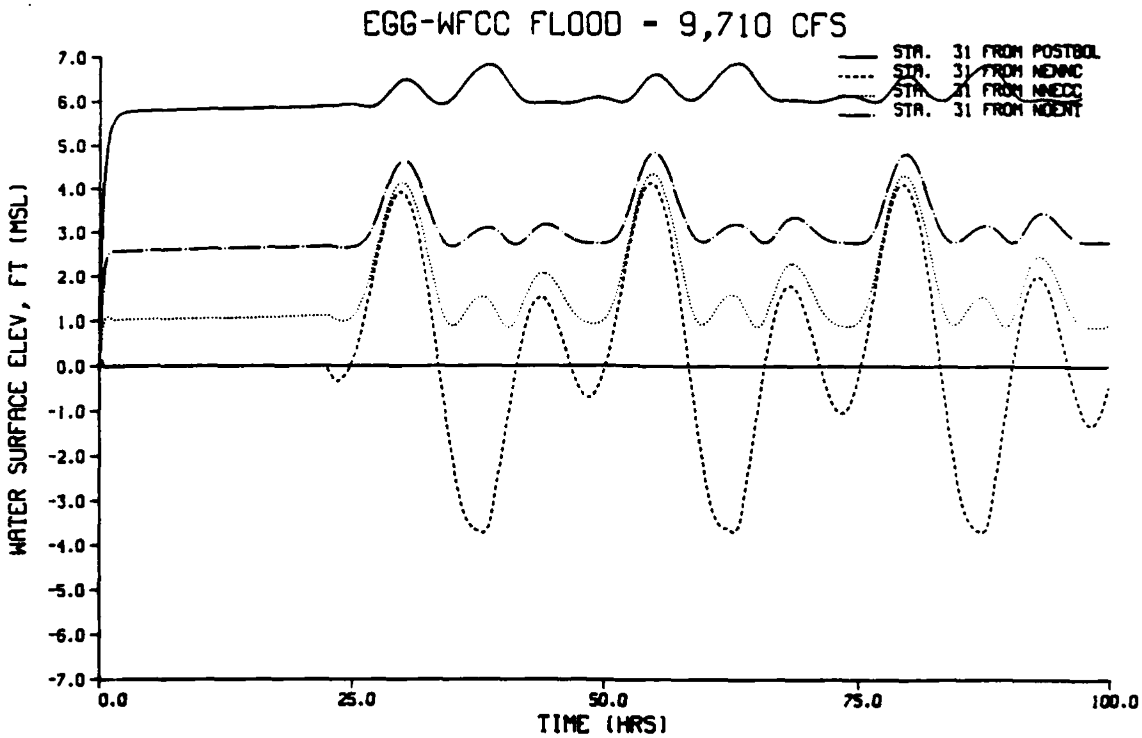


Figure 09. Water surface elevations in Outer Bolsa Bay, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

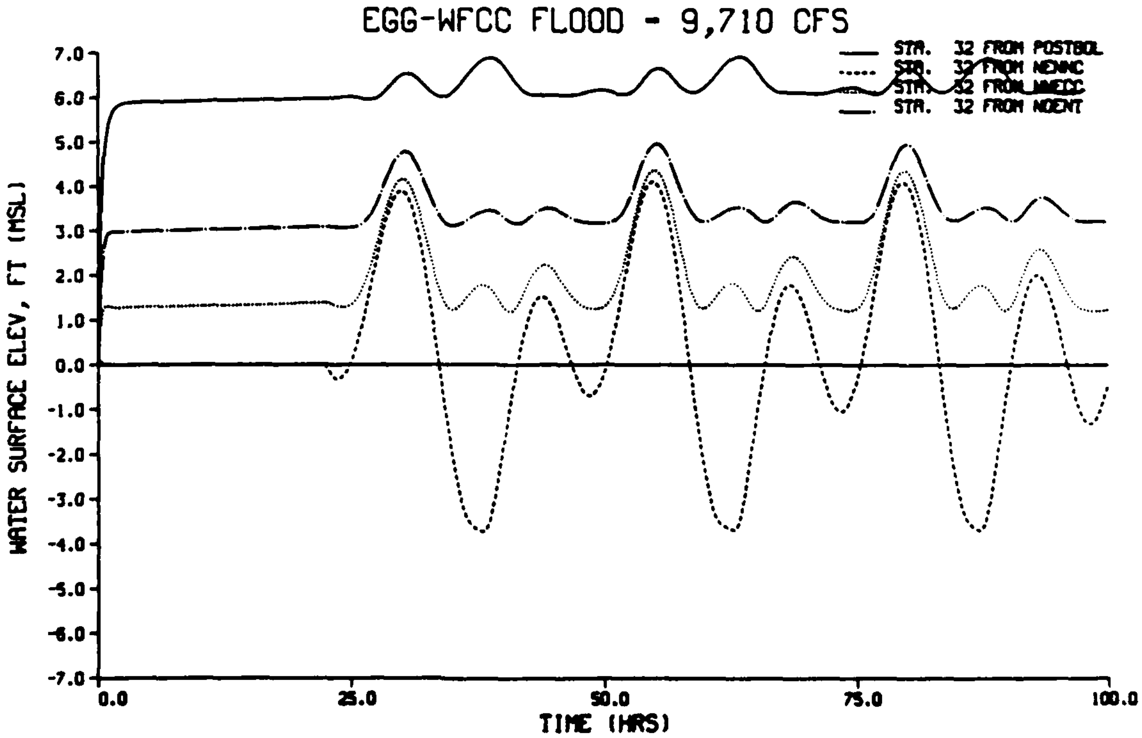


Figure 010. Water surface elevations in Outer Bolsa Bay, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

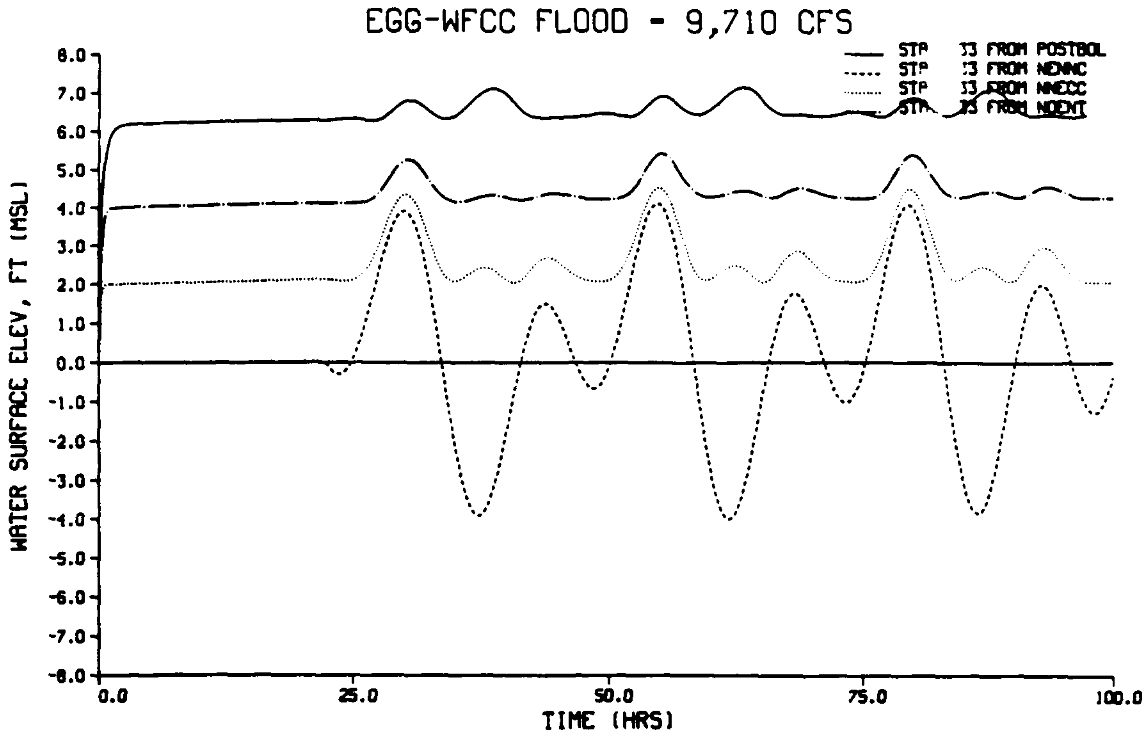


Figure 011. Water surface elevations in Outer Bolsa Bay, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

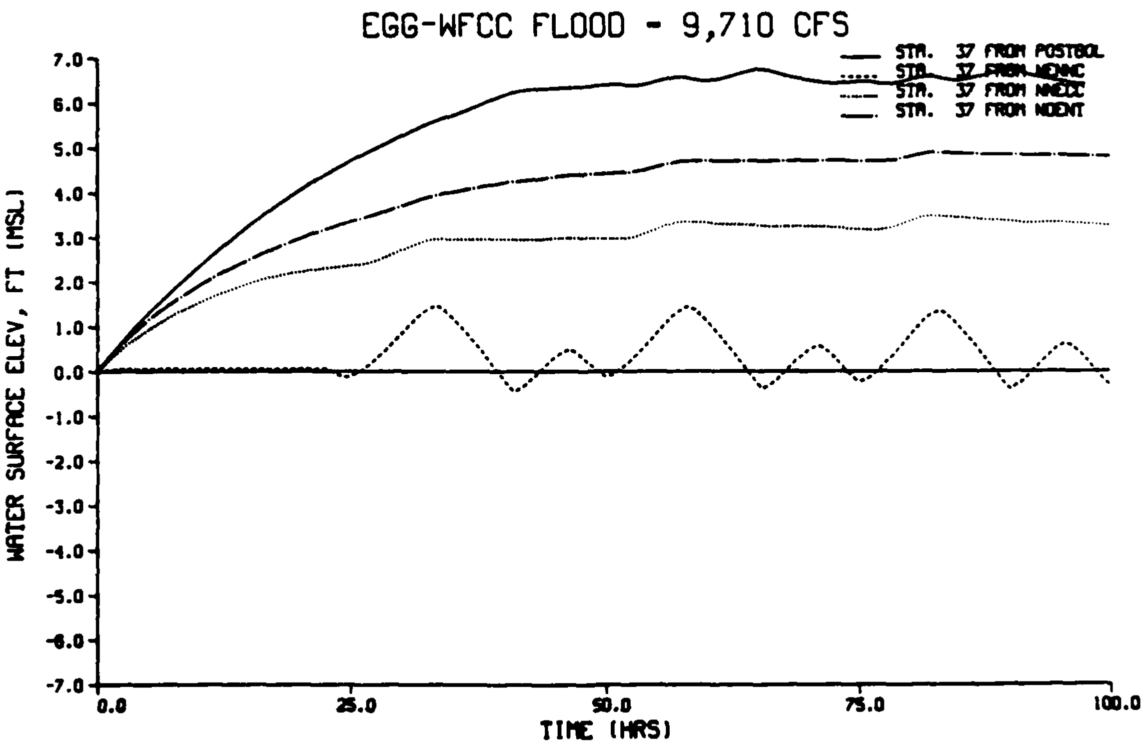


Figure 012. Water surface elevations in Inner Bolsa Bay, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

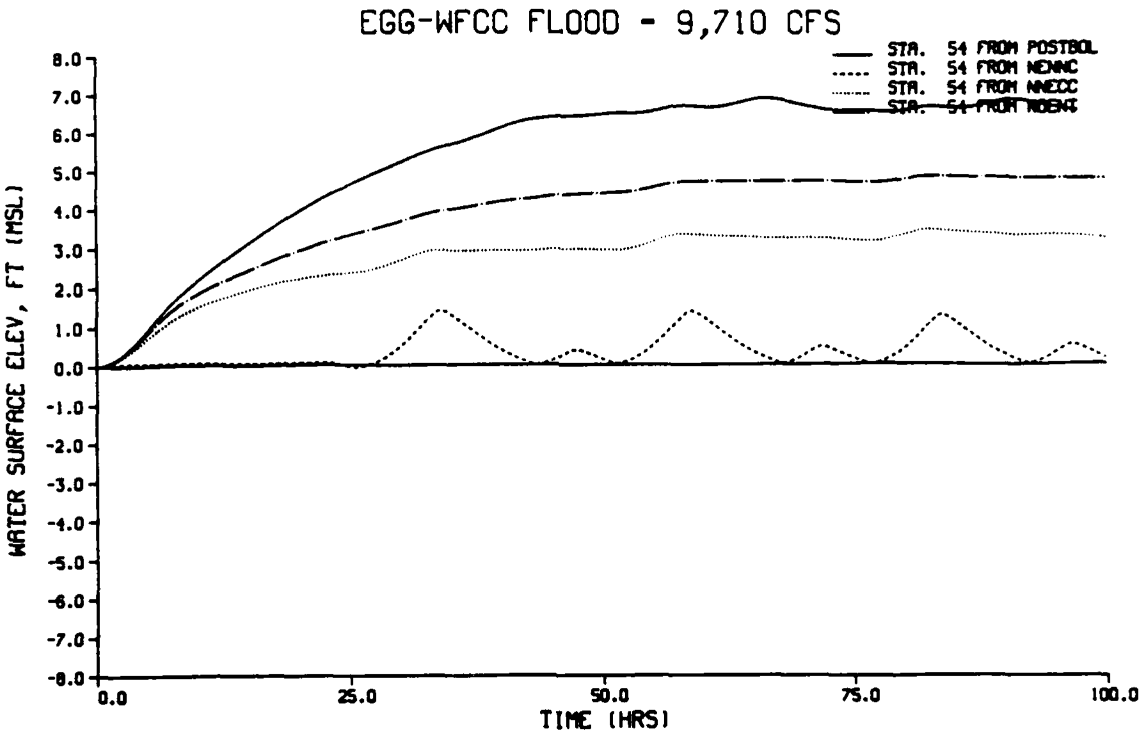


Figure 013. Water surface elevations in DFG muted tidal cell, POSTBOL - existing conditions, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

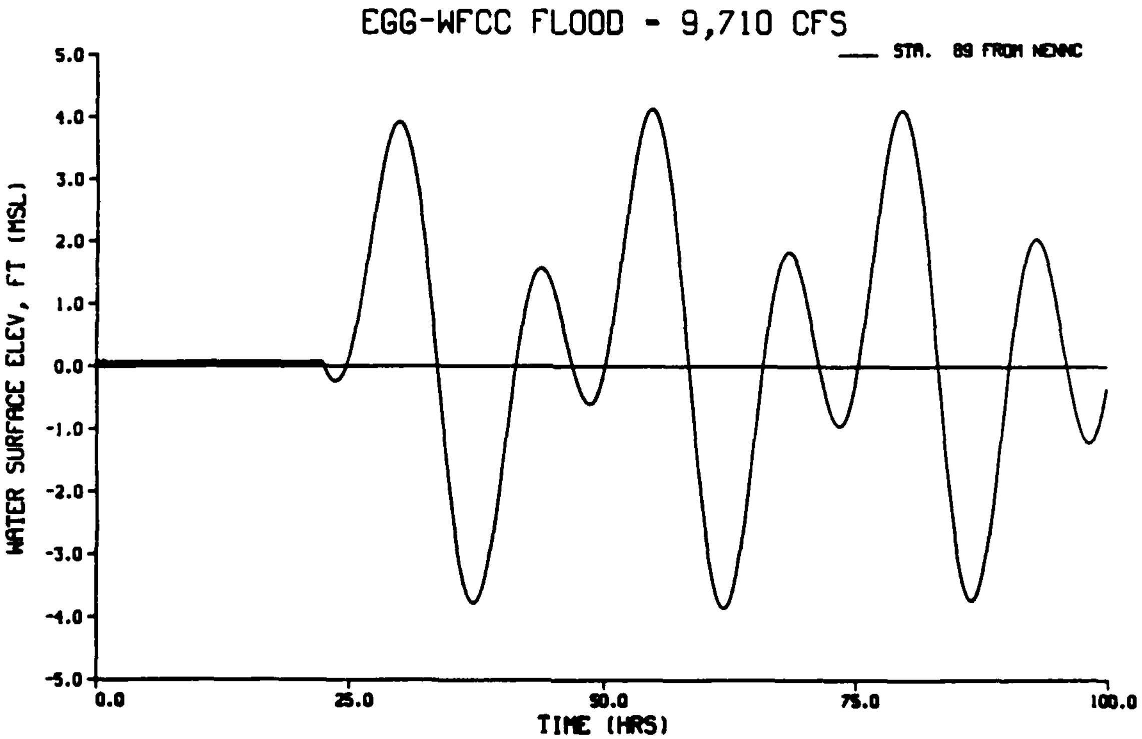


Figure 014. Water surface elevations in proposed marina, NENNC - navigable entrance channel

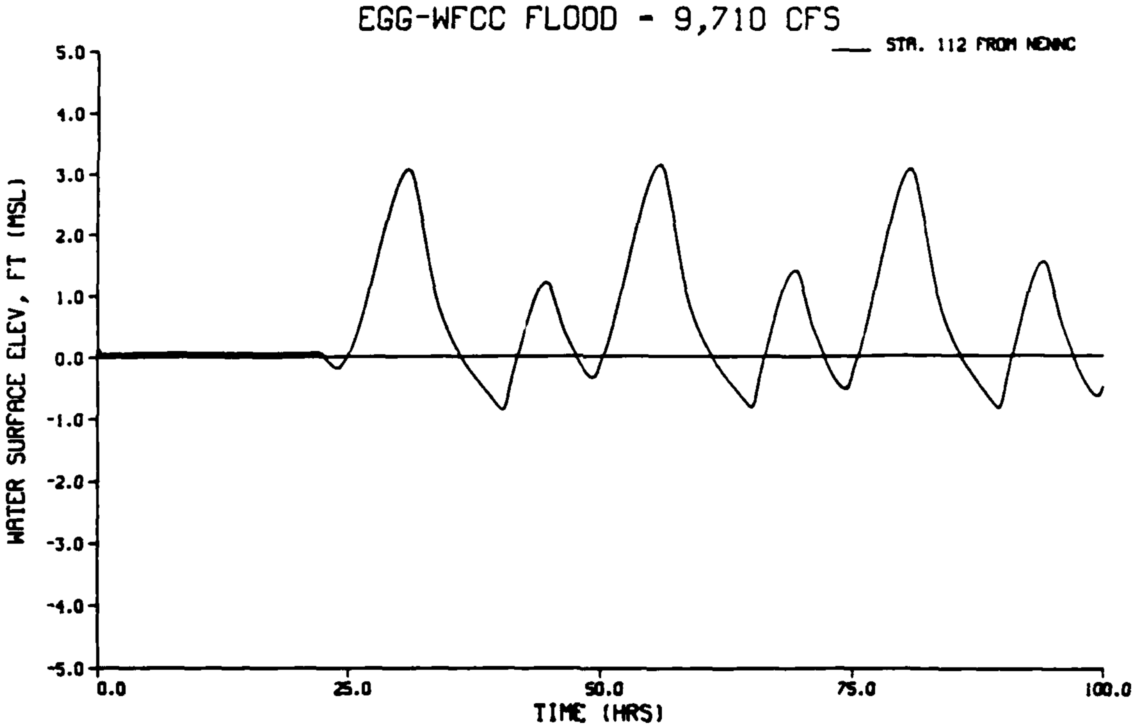


Figure 015. Water surface elevations in proposed full tidal wetlands, NENNC - navigable entrance channel

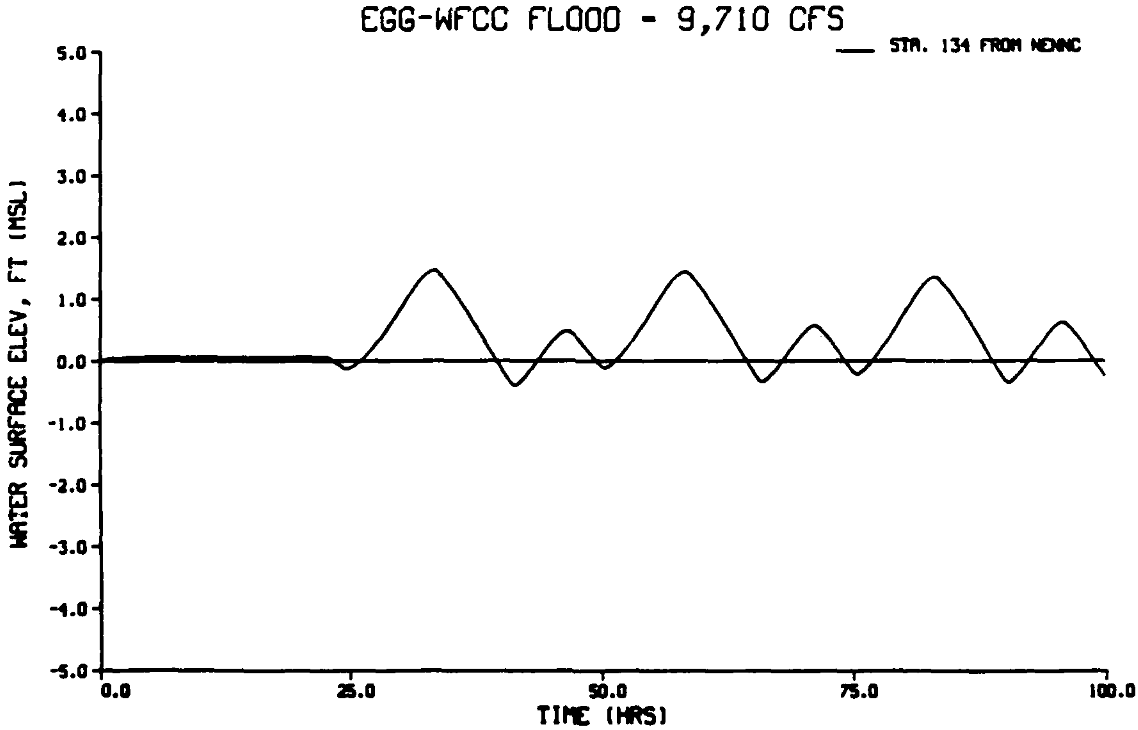


Figure 016. Water surface elevations in proposed muted tidal wetlands, NENNC - navigable entrance channel

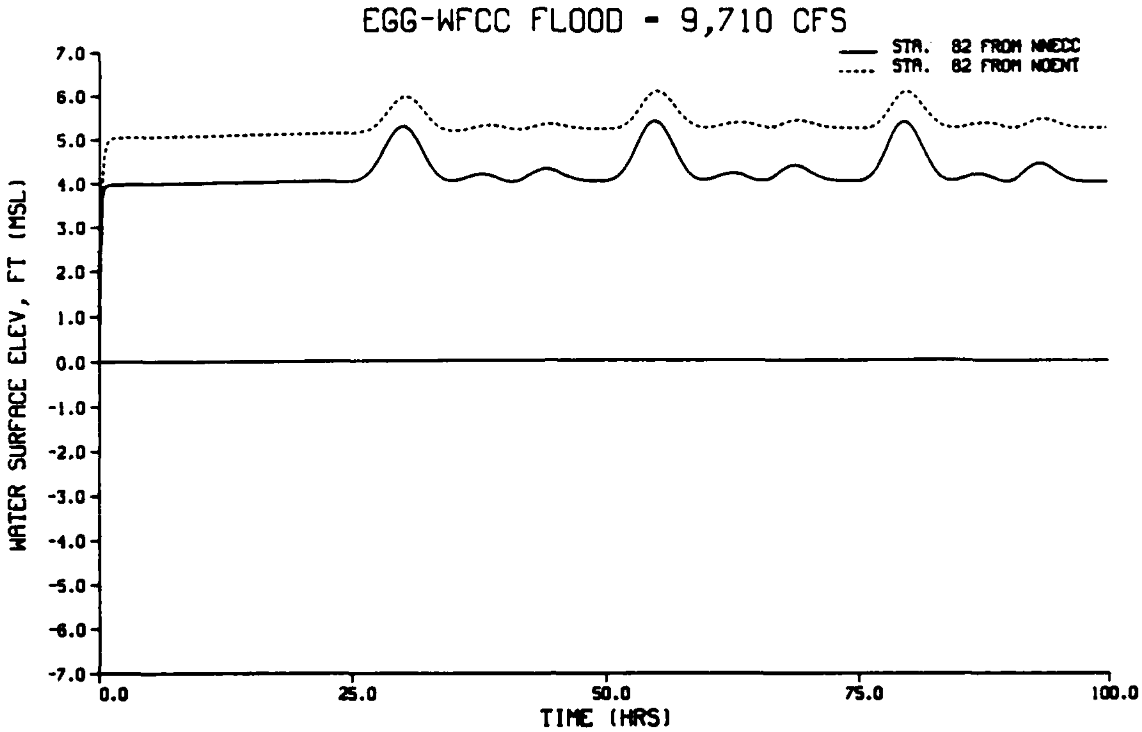


Figure 017. Water surface elevations at EGG-WFCC flood gates, NNECC - non-navigable entrance channel, NOENT - no entrance channel

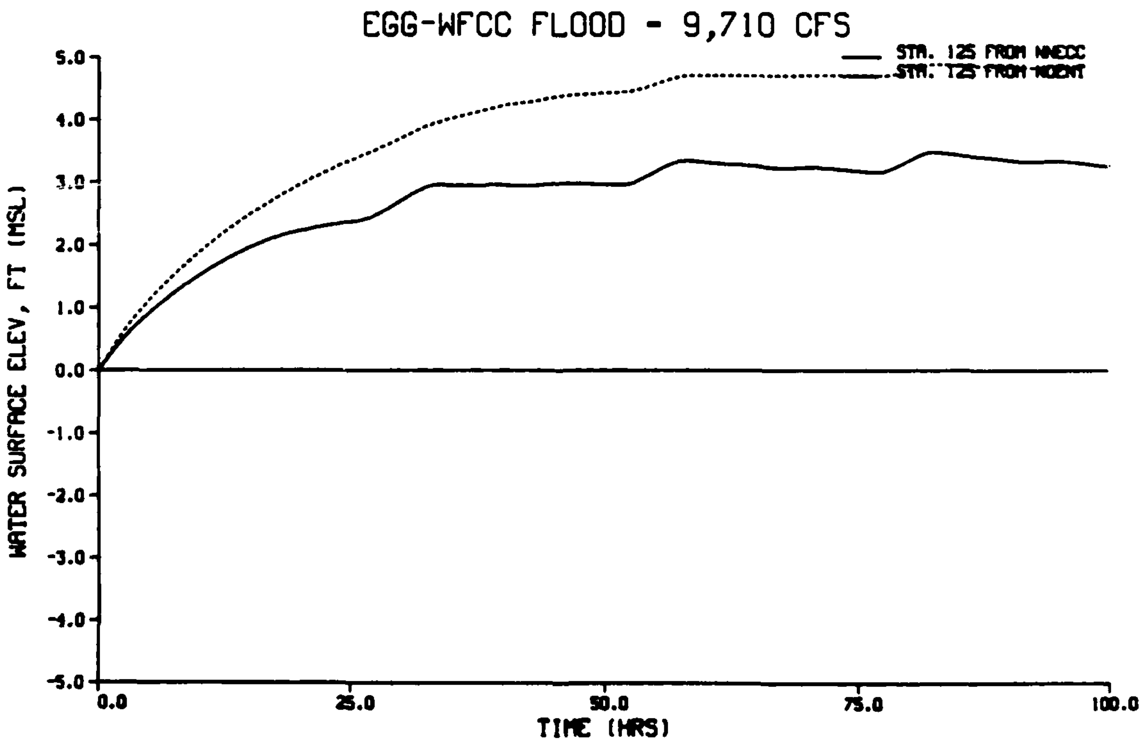


Figure 018. Water surface elevations in proposed muted tidal wetlands, NNECC - non-navigable entrance channel, NOENT - no entrance channel

APPENDIX P:

EAST GARDEN GROVE-WINTERSBURG FLOOD CONTROL CHANNEL (EGG-WFCC) 100-YEAR FLOOD FLOW

AVERAGE CHANNEL VELOCITIES

The locations of links on Figures P1 through P18 are shown on Figures 34, 74, and 91.

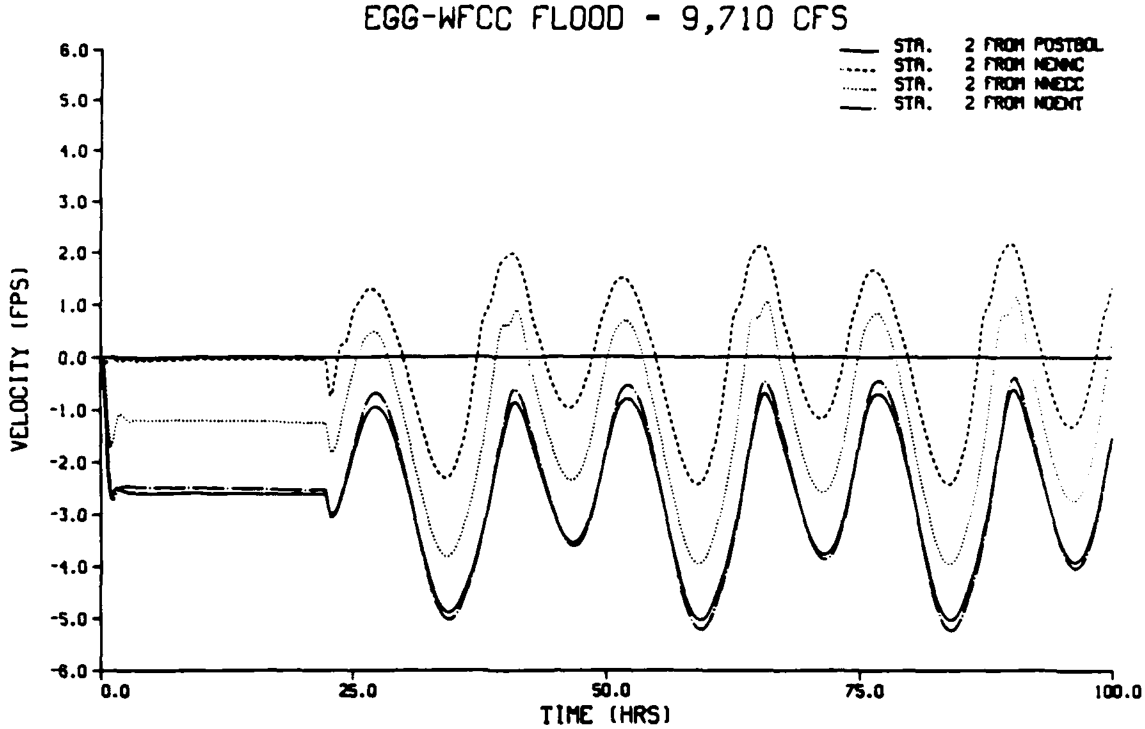


Figure P1. Average channel velocities at Pacific Coast Highway bridge, POSTBOL - existing condition, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

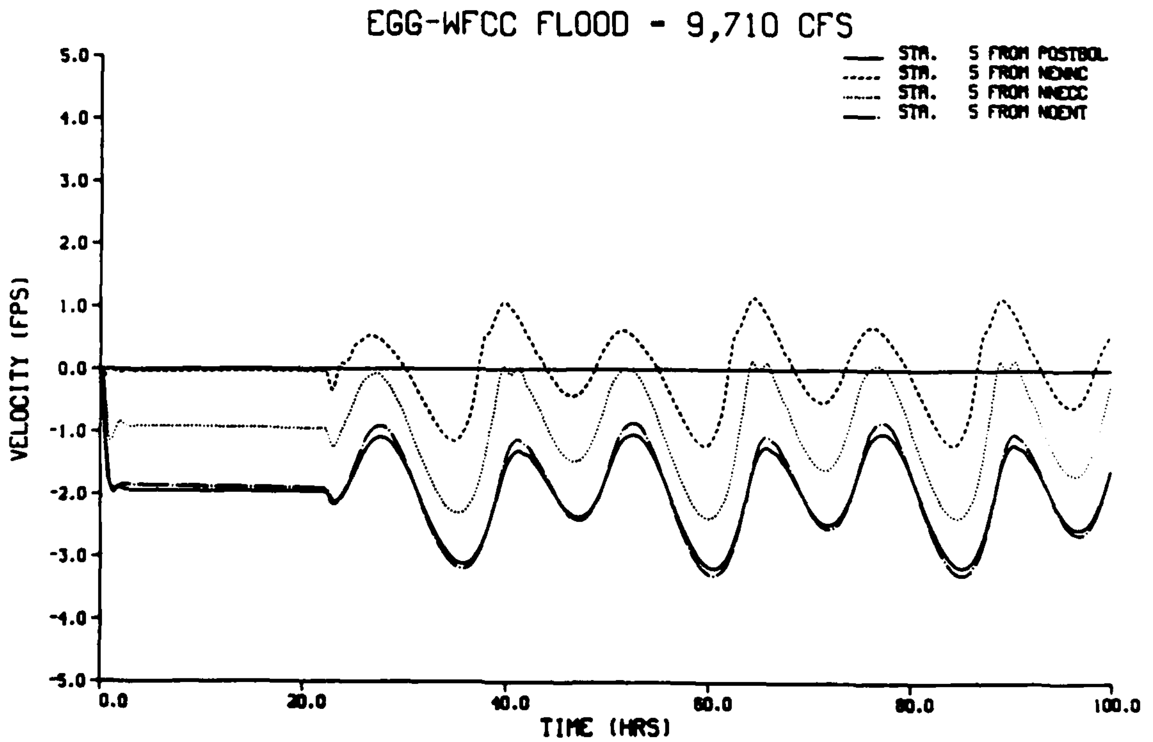


Figure P2. Average channel velocities in Huntington Harbour, POSTBOL - existing condition, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

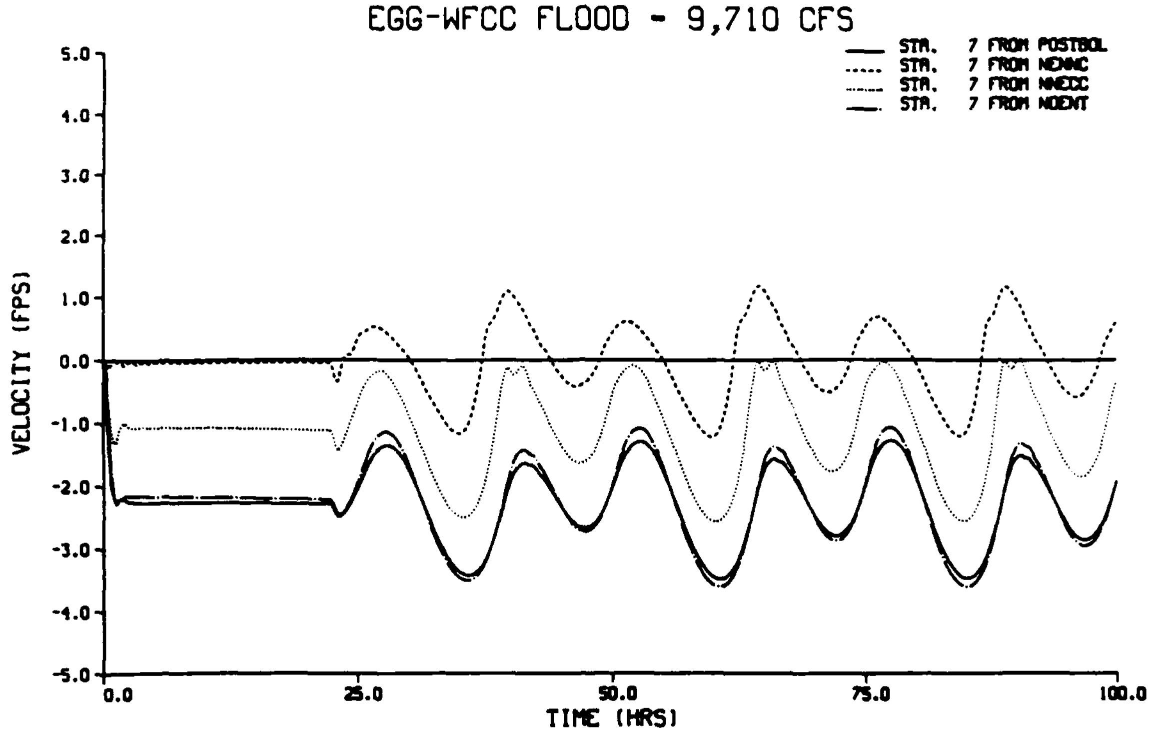


Figure P3. Average channel velocities in Huntington Harbour, POSTBOL - existing condition, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

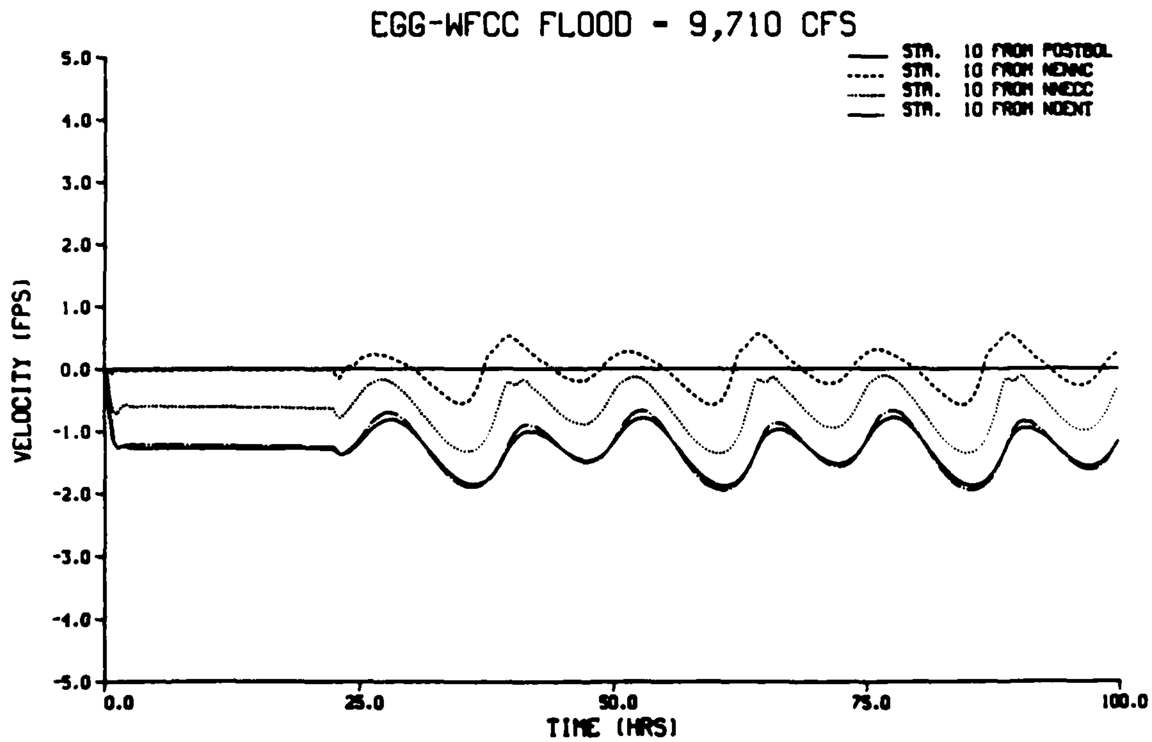


Figure P4. Average channel velocities in Huntington Harbour, POSTBOL - existing condition, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

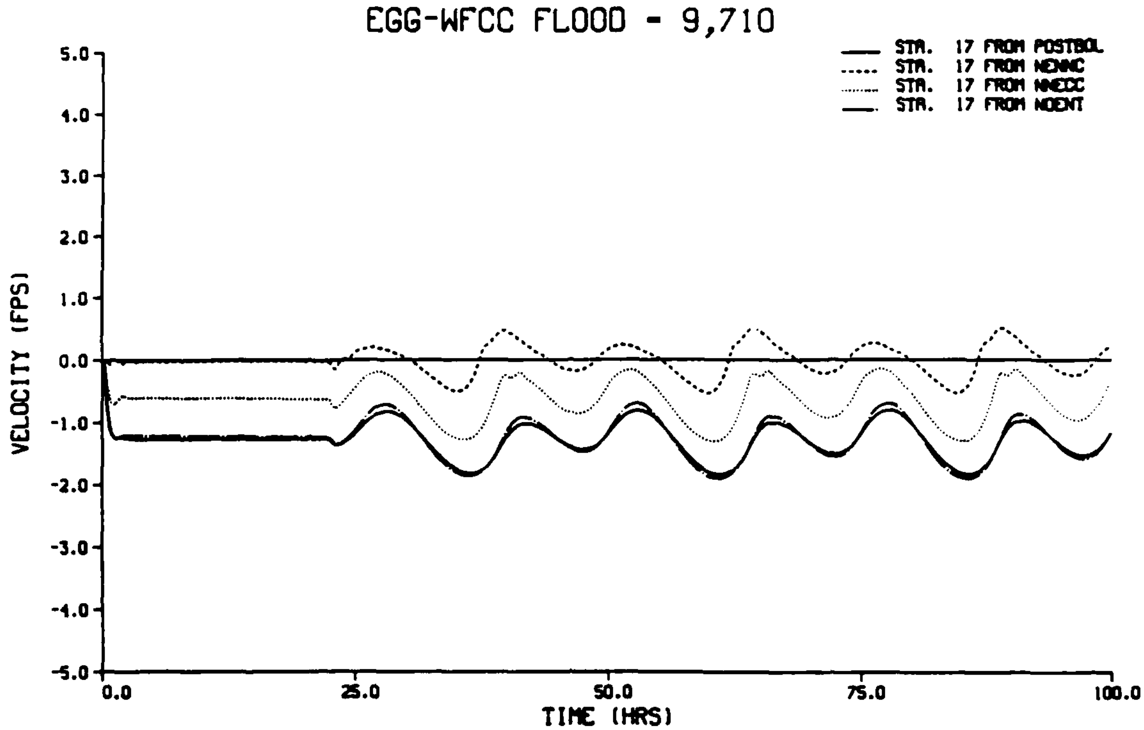


Figure P5. Average channel velocities in Huntington Harbour, POSTBOL = existing condition, NENNC = navigable entrance channel, NNECC = non-navigable entrance channel, NOENT = no entrance channel

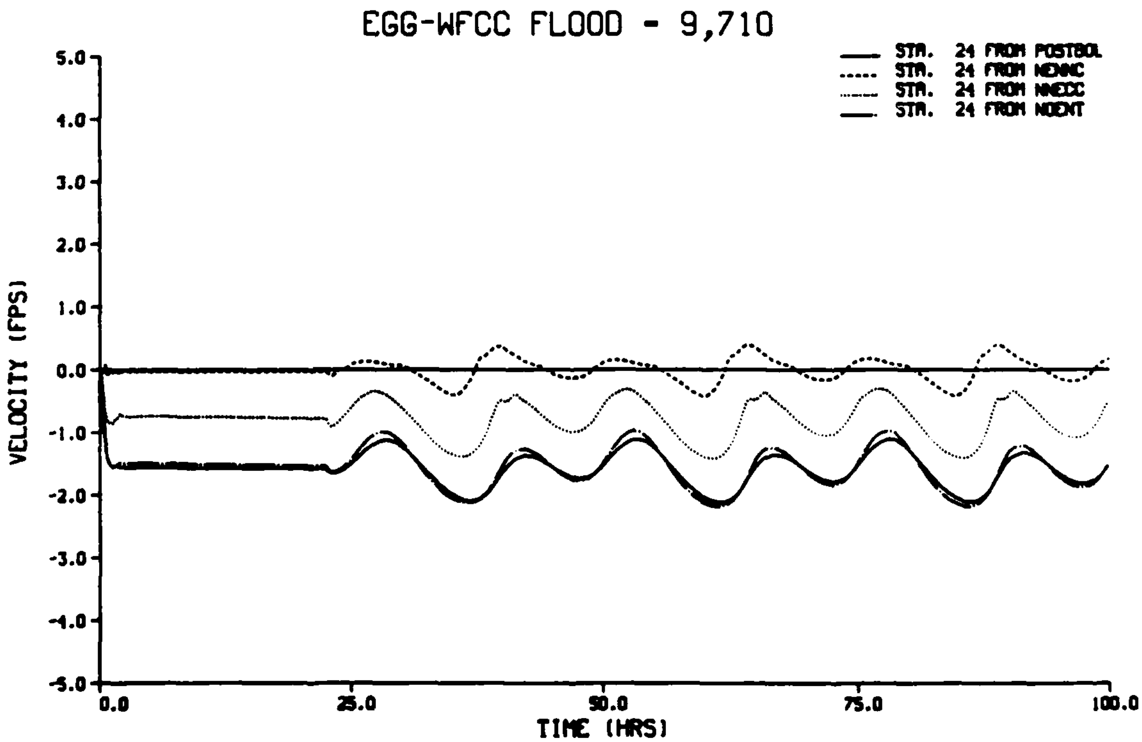


Figure P6. Average channel velocities in Huntington Harbour, POSTBOL = existing condition, NENNC = navigable entrance channel, NNECC = non-navigable entrance channel, NOENT = no entrance channel

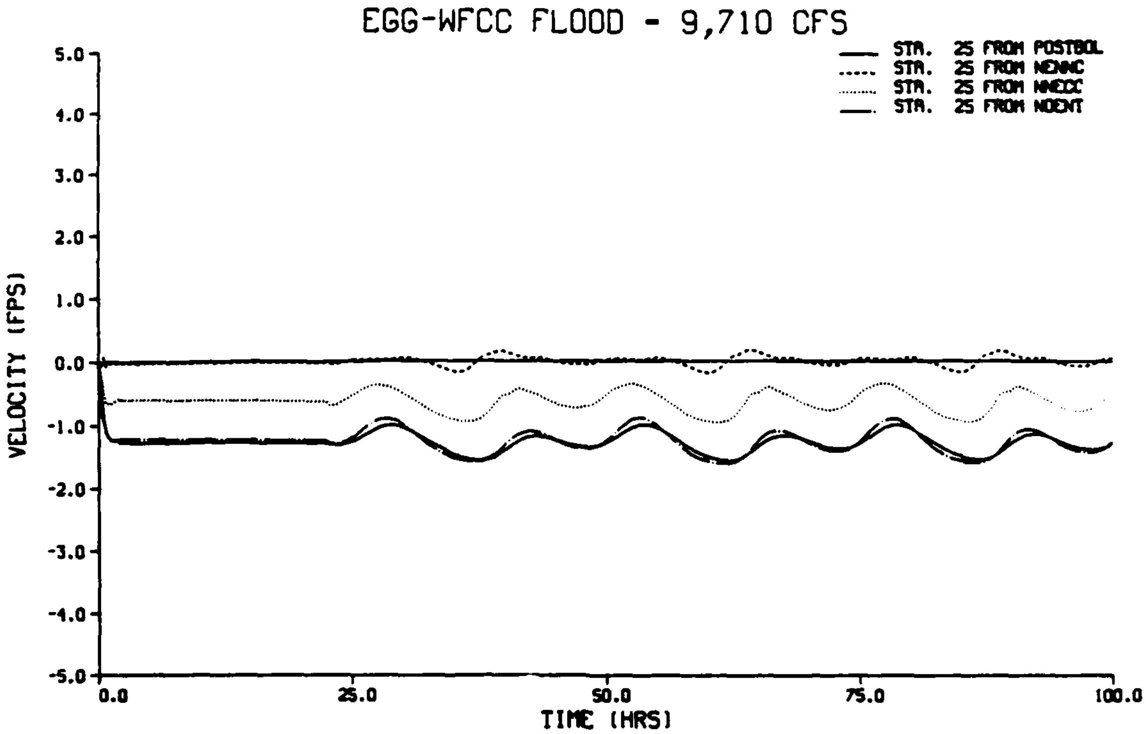


Figure P7. Average channel velocities in Huntington Harbour, POSTBOL - existing condition, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

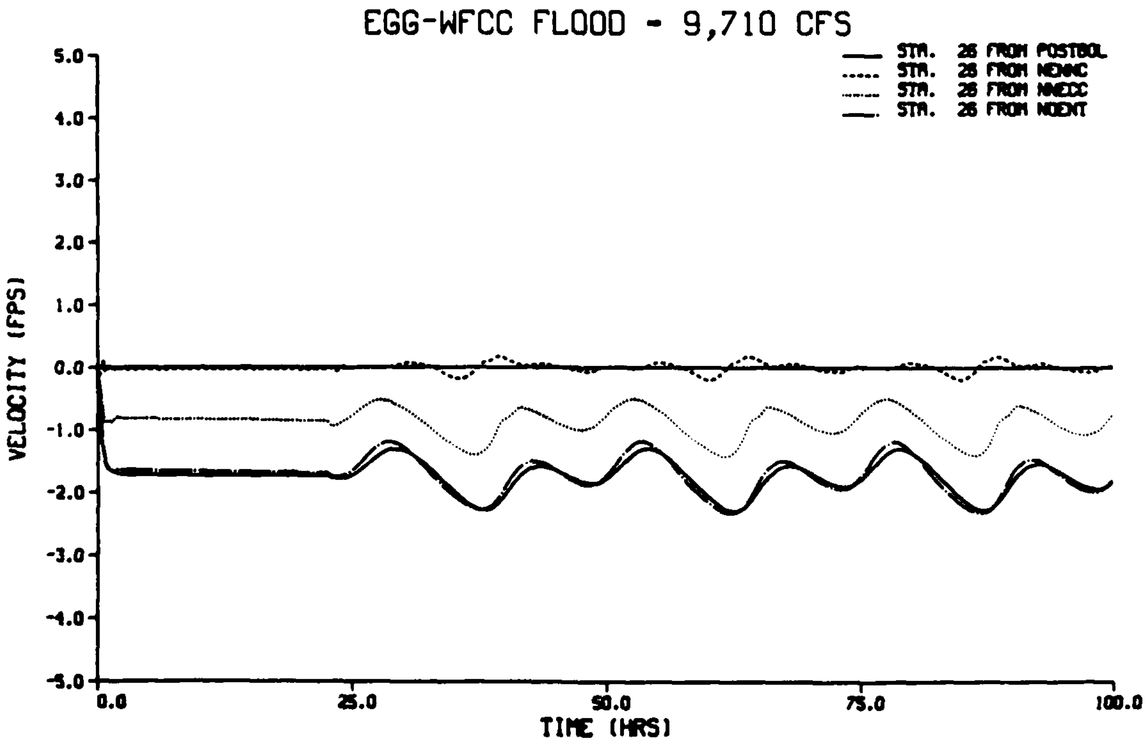


Figure P8. Average channel velocities in Huntington Harbour, POSTBOL - existing condition, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

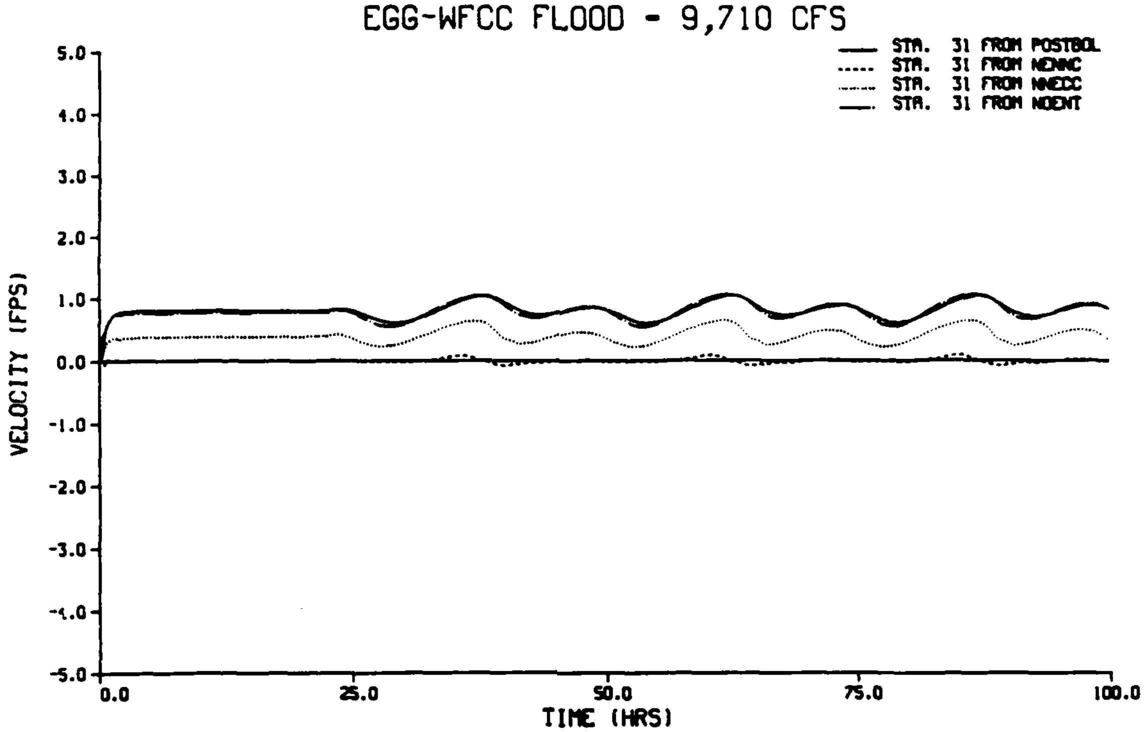


Figure P9. Average channel velocities in Huntington Harbour, POSTBOL - existing condition, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

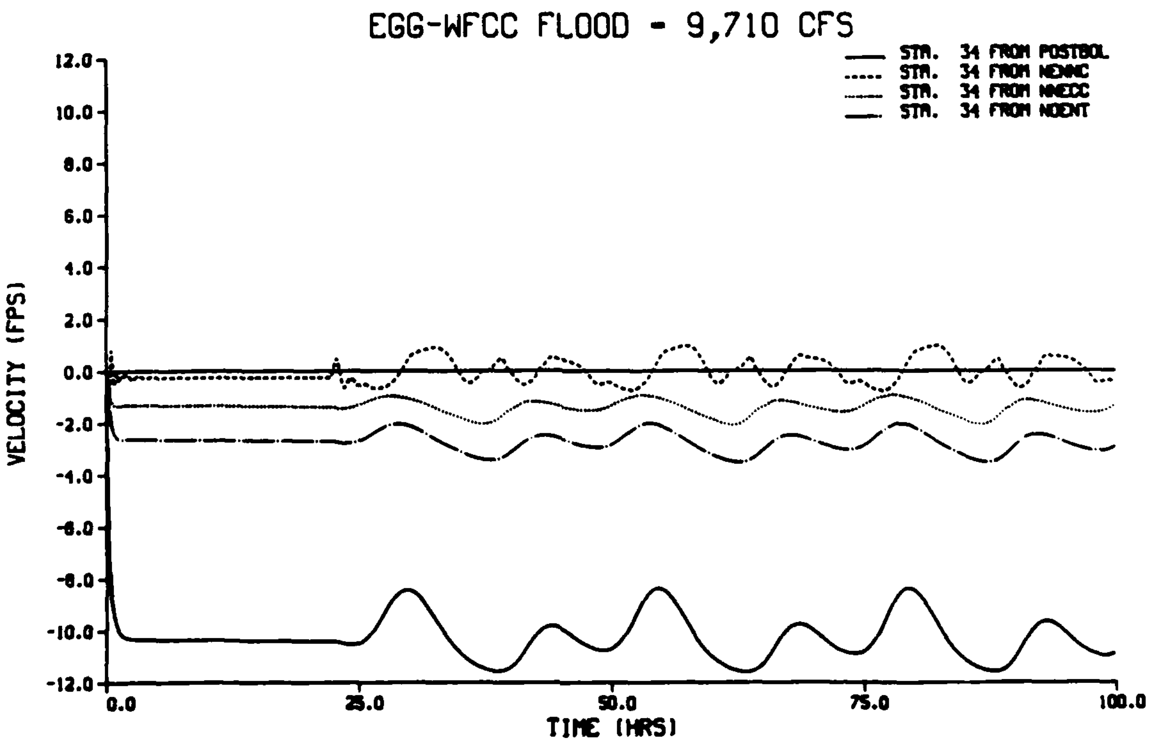


Figure P10. Average channel velocities at Warner Avenue bridge, POSTBOL - existing condition, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

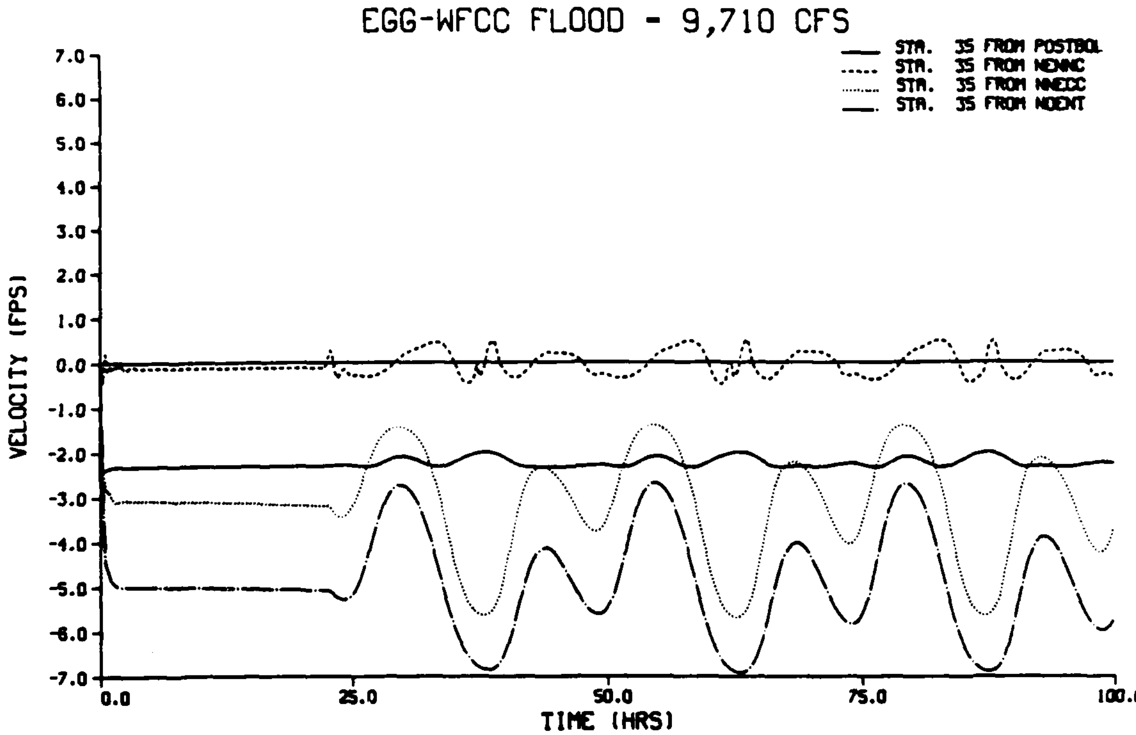


Figure P11. Average channel velocities in Outer Bolsa Bay, POSTBOL - existing condition, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

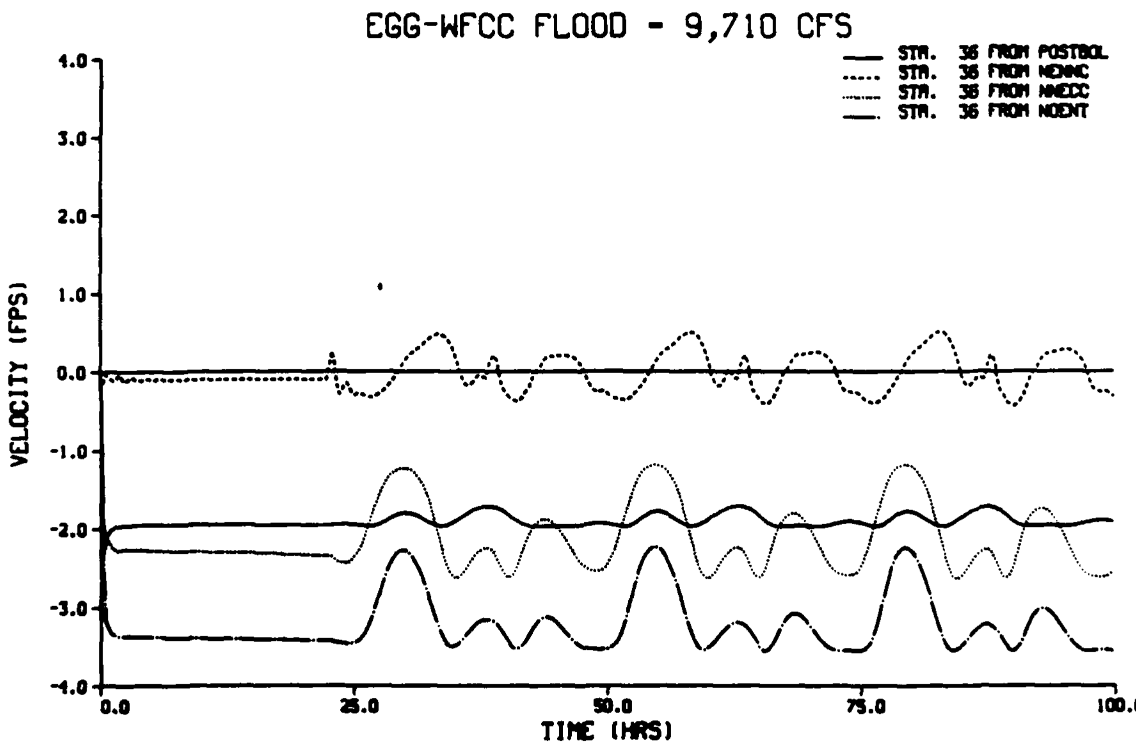


Figure P12. Average channel velocities in Outer Bolsa Bay, POSTBOL - existing condition, NENNC - navigable entrance channel, NNECC - non-navigable entrance channel, NOENT - no entrance channel

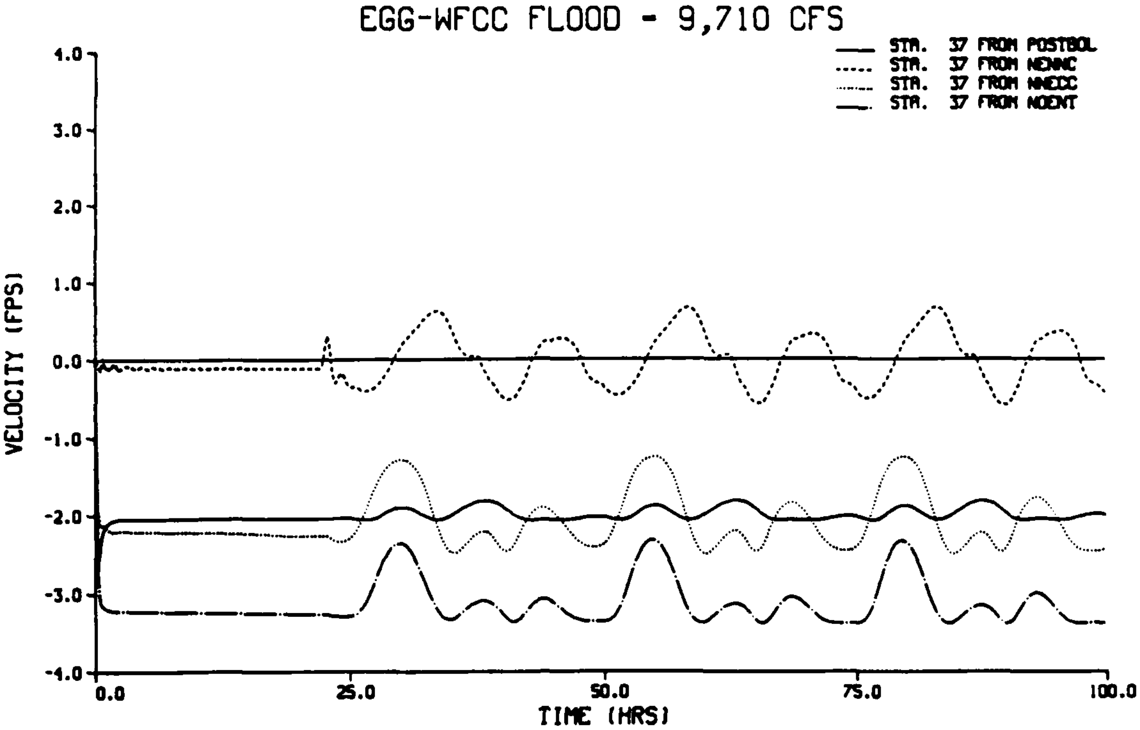


Figure P13. Average channel velocities in Outer Bolsa Bay, POSTBOL = existing condition, NENNC = navigable entrance channel, NNECC = non-navigable entrance channel, NOENT = no entrance channel

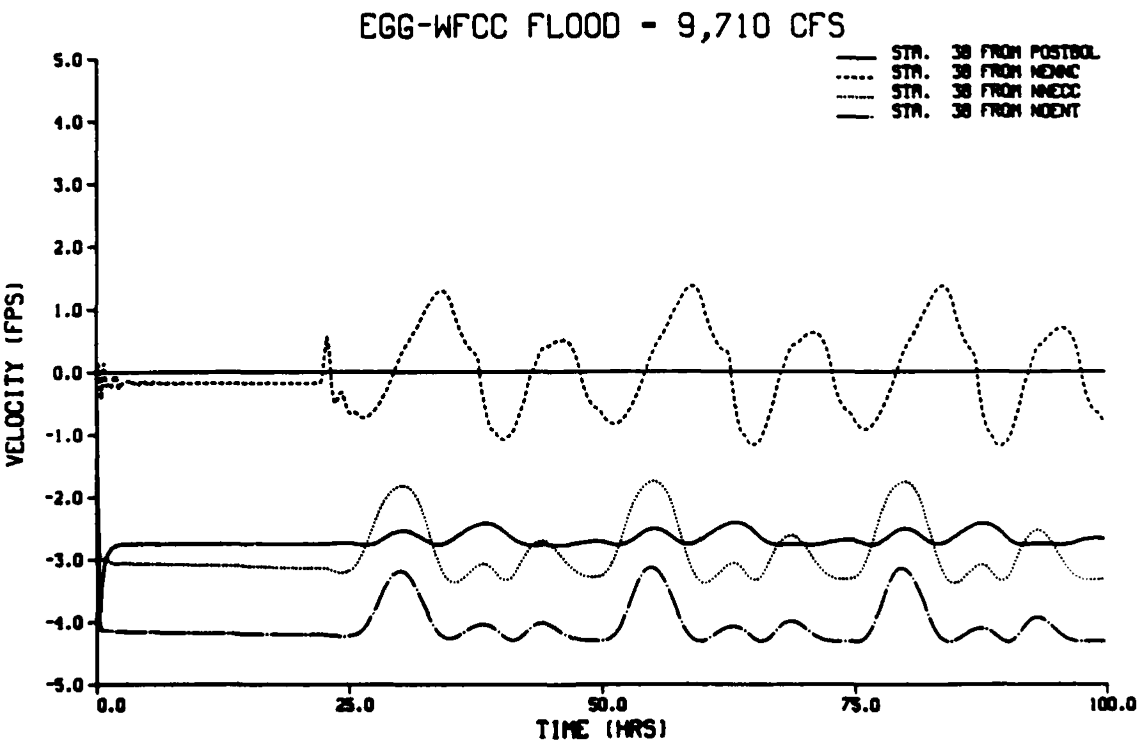


Figure P14. Average channel velocities in Outer Bolsa Bay, POSTBOL = existing condition, NENNC = navigable entrance channel, NNECC = non-navigable entrance channel, NOENT = no entrance channel

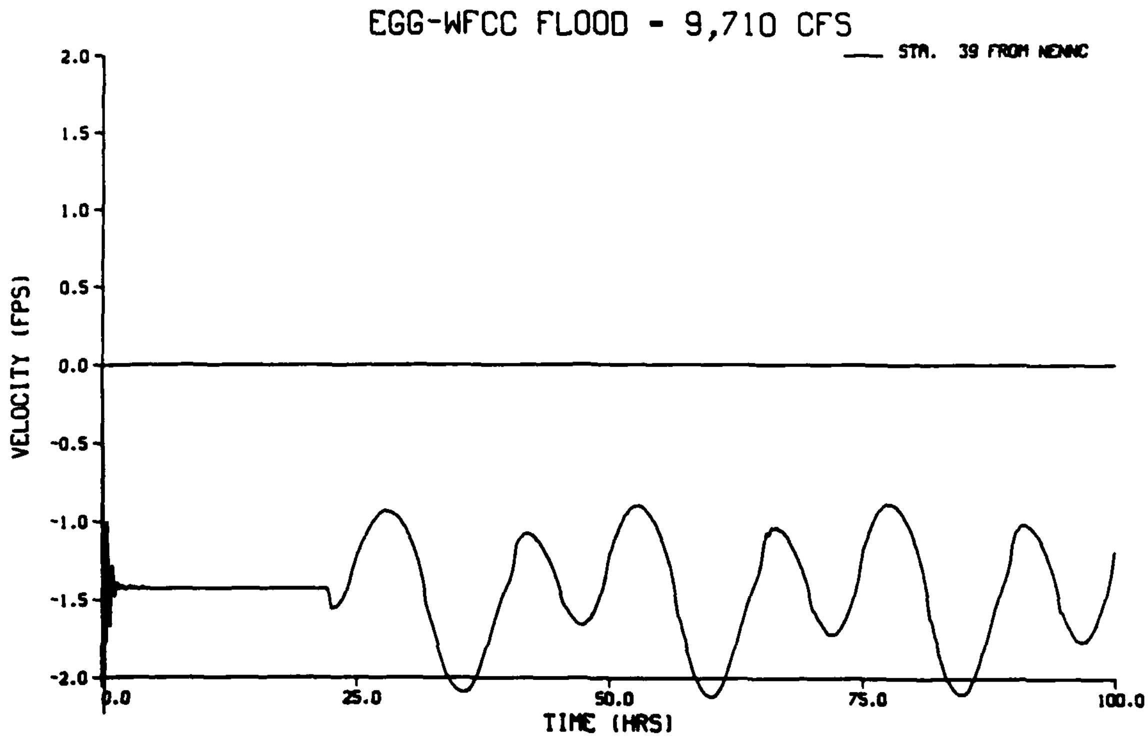


Figure P15. Average channel velocities in proposed marina channel, NENNC - navigable entrance channel

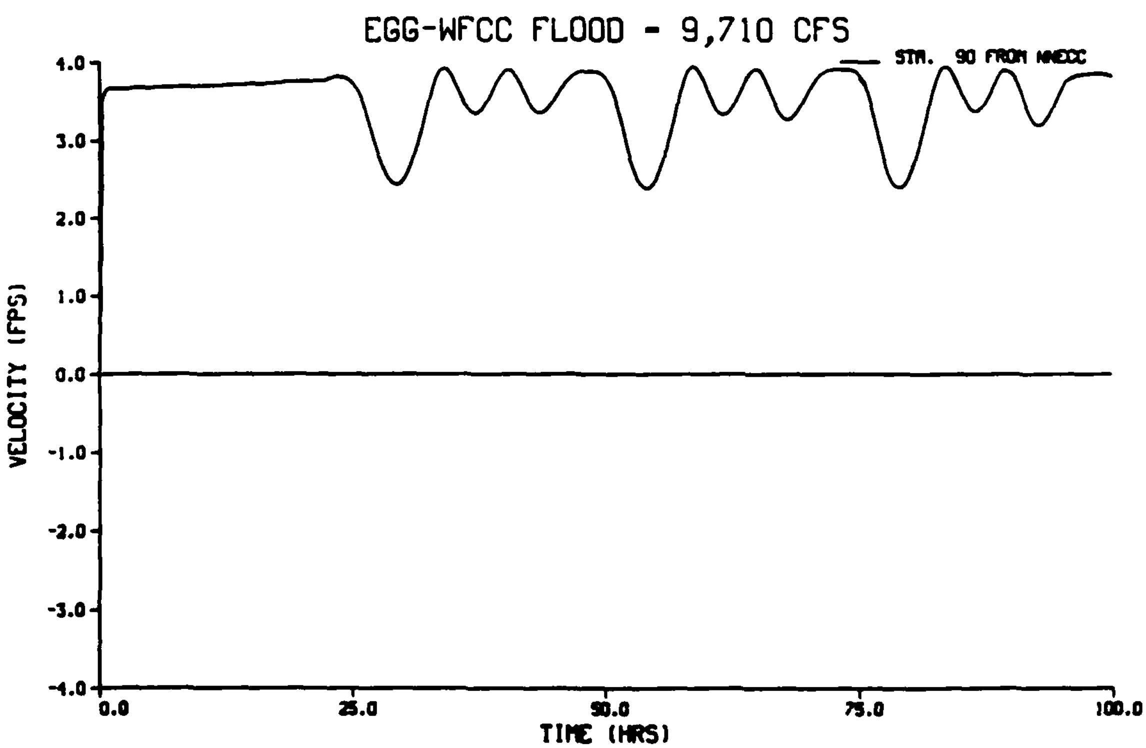


Figure P16. Average channel velocities in proposed entrance channel, NNECC - non-navigable entrance channel

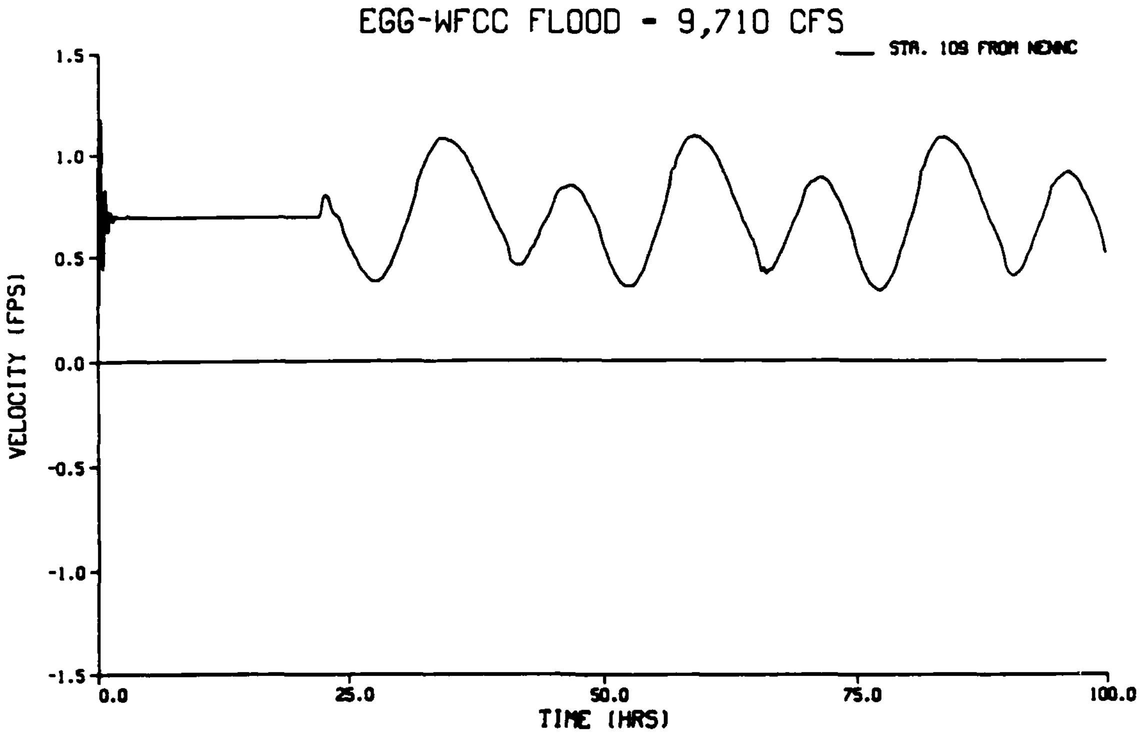


Figure P17. Average channel velocities in proposed entrance channel, NENNC - navigable entrance channel

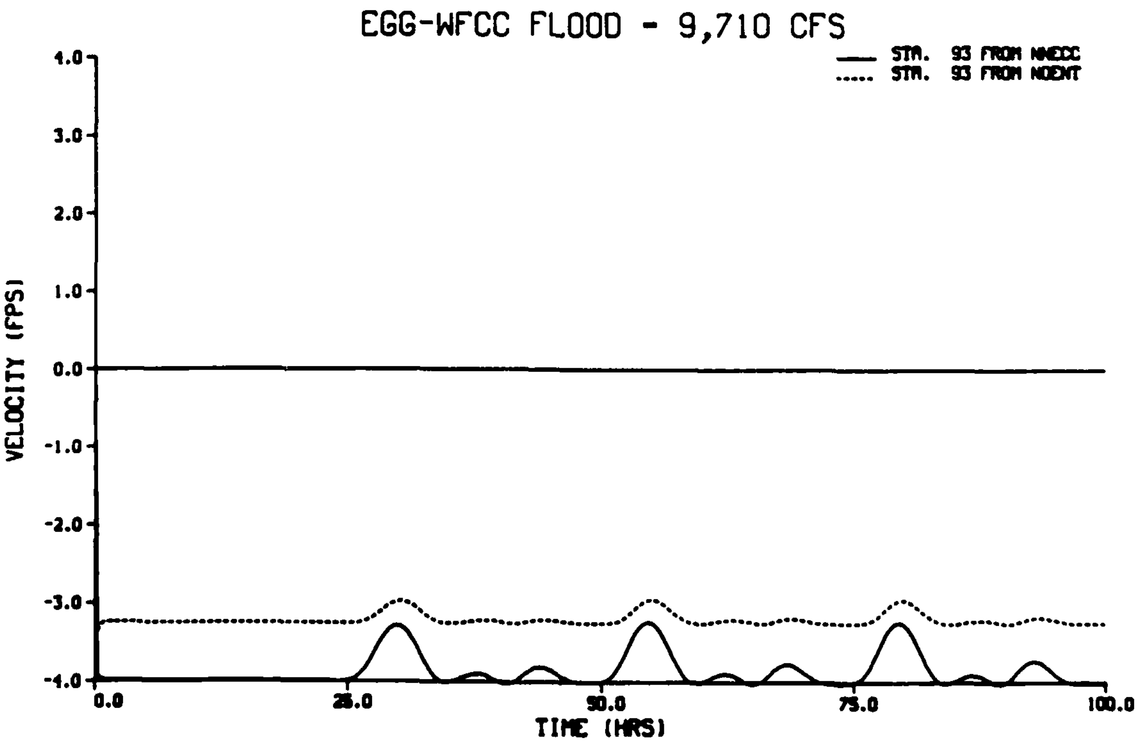


Figure P18. Average channel velocities in EGG-WFCC, NNECC - non-navigable entrance channel, NOENT - no entrance channel

APPENDIX Q:

DYE STUDIES IN HUNTINGTON HARBOUR AND BOLSA BAY

APPENDIX Q

DYE STUDIES IN HUNTINGTON HARBOUR AND BOLSA BAY

Q1. To assist in the calibration of the transport model, Tekmarine (1988) was engaged by WES through SPL to conduct field studies of the existing water circulation patterns in the Bolsa Bay complex using dye tracing techniques. The study of the tide-induced circulation patterns involved two dye release and tracking operations, one in Huntington Harbour and the other in Bolsa Bay.

Q2. To track the transport and dispersion of the dye, water samples were repeatedly taken at several specific locations (stations) in the harbor and bay system. Figure Q1 shows the locations of these stations, and Table Q1 provides details of each station along with the location of the station in terms of the nodal system utilized by the WES numerical models. The concentration of dye in the samples was later determined in the laboratory using a fluorometer. This approach was selected for these studies in order to obtain maximum reliability of the sample testing through improved power supply conditions for the fluorometer, cleanliness, sample temperature stability, and to provide maximum mobility while conducting the sampling operations in the field.

Q3. At the primary stations, samples were obtained approximately hourly, although more frequent sampling was done at selected stations during the early portions of each study to attempt to pinpoint the passage of the highly concentrated dye plume centroid. At the secondary stations, samples were only obtained for short periods to provide intermediate dye concentration information. Where possible, samples were obtained at about mid-channel and mid-depth. If water depth or access limitations prevented reaching this spot, samples were taken from the side of the channel using a rod that reached approximately 15 ft from the shoreline. To prevent dye concentration decay due to sunlight, the samples were stored in a darkened box immediately after they were collected. Rhodamine WT was used as the tracer dye since it is well suited to this type of study, has very limited environmental effects, and its concentration can be accurately determined at very low concentrations. Background levels of fluorescence were obtained prior to releasing the dye.

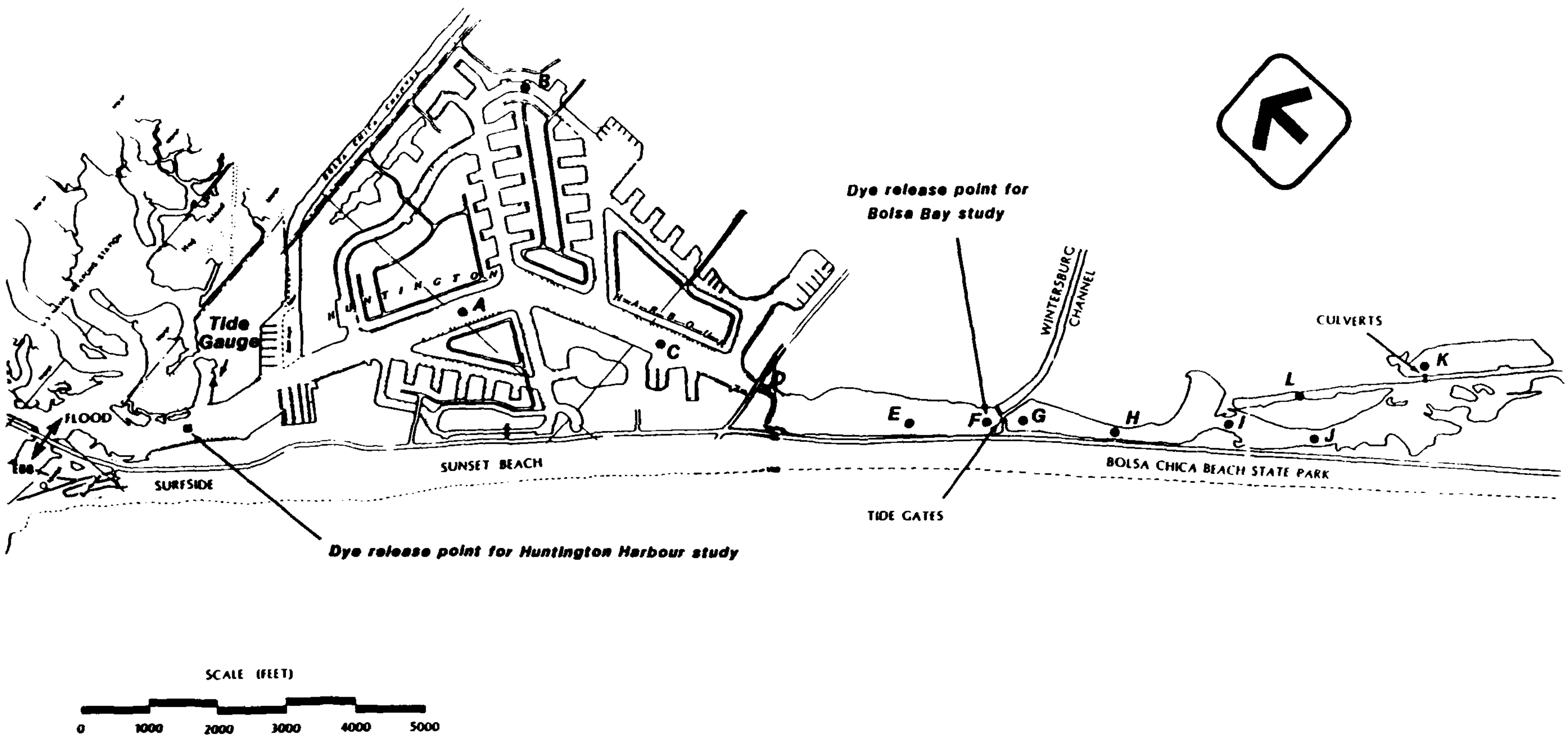


Figure Q1. Dye release stations for tide-induced circulation in Huntington Harbour, Outer Bolsa Bay, Inner Bolsa Bay, and DFG cell (after Tekmarine 1988)

Table Q1

Description of Sampling Stations

Huntington Harbour, Outer Bolsa Bay, and Inner Bolsa Bay

Station	Description of Sampling Site	Location of Station Relative to WES Model Nodes
A *	Middle of main channel in Huntington Harbour	Node 9
B *	Middle of eastern back-channel in Huntington Harbour	Node 23
C *	Middle of main channel in Huntington Harbour	Node 24
D *	Mid-channel just south of Warner Ave. Bridge (secondary station for Bolsa Bay study)	Halfway between Nodes 25 & 29
E	Western edge of Outer Bolsa Bay	Node 32
F *	Mid-channel north of tide gates separating Outer and Inner Bolsa Bay	Node 33
G	Mid-channel south of tide gates	Node 34
H	Western edge of Inner Bolsa Bay	Node 37
I *	Mid-channel of Inner Bolsa Bay, off foot-bridge	Halfway between Nodes 37 & 38
J *	Western edge of Inner Bolsa Bay	Node 39
K *	Just off eastern end of culverts entering DFG cell (Cell 3)	Node 53
L	Eastern edge of narrow channel located east of large bird nesting island	200 ft north of Node 44

Source: Tekmarine, Inc. (1988)

* Denotes primary sampling station.

Huntington Harbour Dye Study

Huntington Harbour field operations

Q4. The dye study in Huntington Harbour was executed on 23 September 1988 and timed to begin just after the occurrence of the lower low tide predicted by the National Oceanic and Atmospheric Administration (NOAA) at 0212 Pacific Daylight Time (PDT). A total of 16.3 liters of Rhodamine WT (20 percent solution) was released in the main channel near the entrance to the harbor at 0225-0235 PDT. The dye was dumped into the propellor wash of a small boat motoring slowly around the injection area. Zero hour for the dye release was specified as 0230 PDT.

Q5. To get an indication of the distribution of the dye immediately following release, samples were taken at various depths below the surface in roughly the center of the injection area. The five samples, taken about 15 to 20 min after injection, showed the following concentrations:

Depth	Concentration
Surface (2 samples)	170 ppb, 600 ppb
2 ft	120 ppb
4 ft	35 ppb
7 ft	23 ppb

Q6. Sampling, which commenced shortly after release of the dye, was conducted at Stations A, B, C, and D. During about the first two hours, the operation focused on sampling at Stations A and C as frequently as possible to record the rapid passage of the initial peak dye concentration. Since the dye was slower to reach the other stations, Station B was first visited about 2.25 hr after injection, and Station D about 2.75 hr after injection. As the peak dye concentrations were expected to have decreased, sampling reverted to a schedule where all four stations were sampled approximately hourly until the end of the study, approximately 18 hr after the dye release.

Q7. Stations A, B, and C were sampled from a small boat operating in the harbor channels. To obtain a sample at these stations, a jar with a perforated lid was quickly lowered to about mid-depth using a rod/jar holder and held at depth while the jar slowly filled. Station D was sampled from the northeast channel shoreline just south of the Warner Avenue bridge. Using an extendable rod, the samples were obtained very close to mid-channel. Although

this station was to have been located further south in Outer Bolsa Bay, steep channel slopes to the east and intervening mudflats to the west prevented access except at the street overcrossing. The low elevation of the bridge precluded the use of a boat in this area.

Huntington Harbor dye study results

Q8. Figures Q2 through Q5 present time-histories of the mid-depth concentrations at the four sampling stations. Figure Q6 shows the tidal fluctuations during the study. In some cases, samples were obtained at the surface as well as at mid-depth to assess the extent of mixing that was taking place in the channel cross-section.

Q9. Review of Figures Q4 and Q5 reveals the presence of unexpectedly high concentrations at the onset of sampling at Stations C and D. Since these singular measurements occur before the numerical model predictions indicate that any dye should reach these stations, it seems unlikely that they reflect dye that has followed a course along the harbor channels. These high readings may have been caused by an unknown constituent in the water. It is also possible that, although extreme care was exercised, the samples may have been

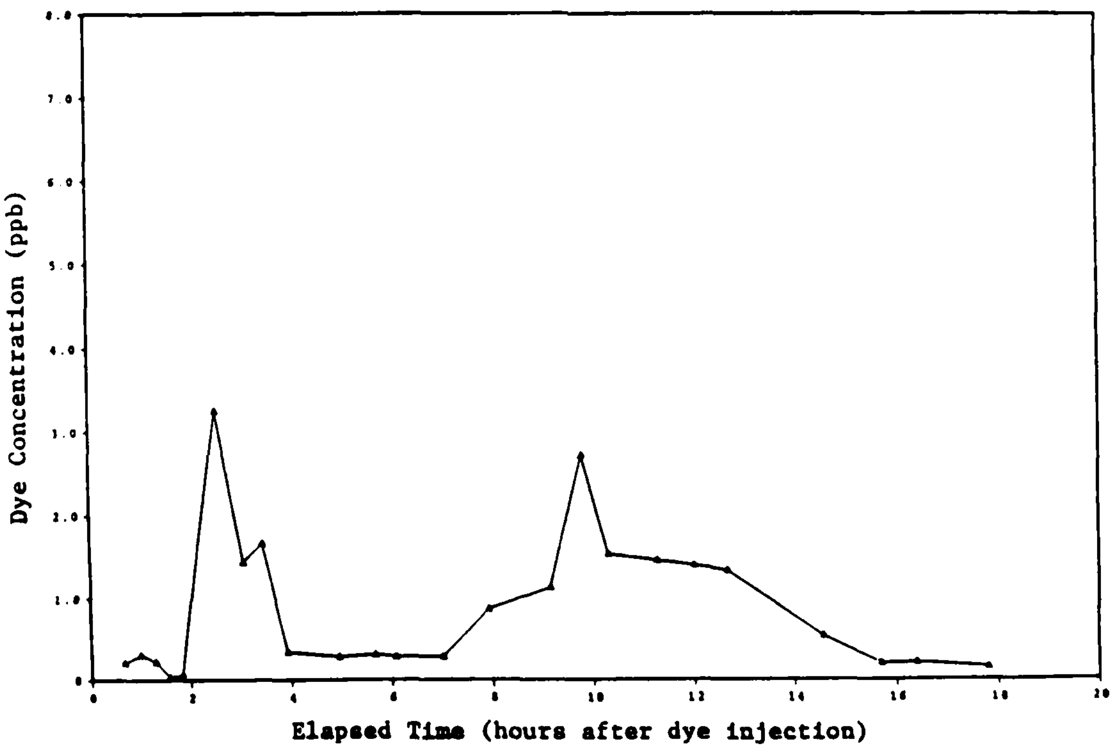


Figure Q2. Huntington Harbour dye study, concentration at Station A (after Tekmarine 1988)

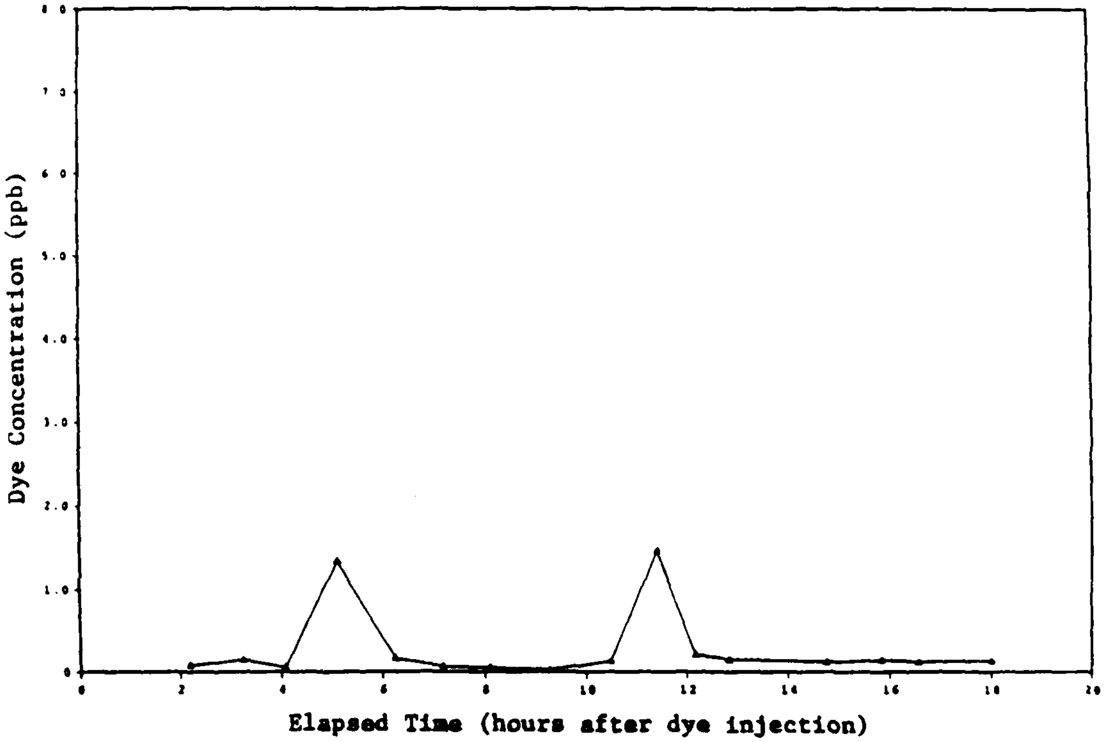


Figure Q3. Huntington Harbour dye study, concentration at Station B (after Tekmarine 1988)

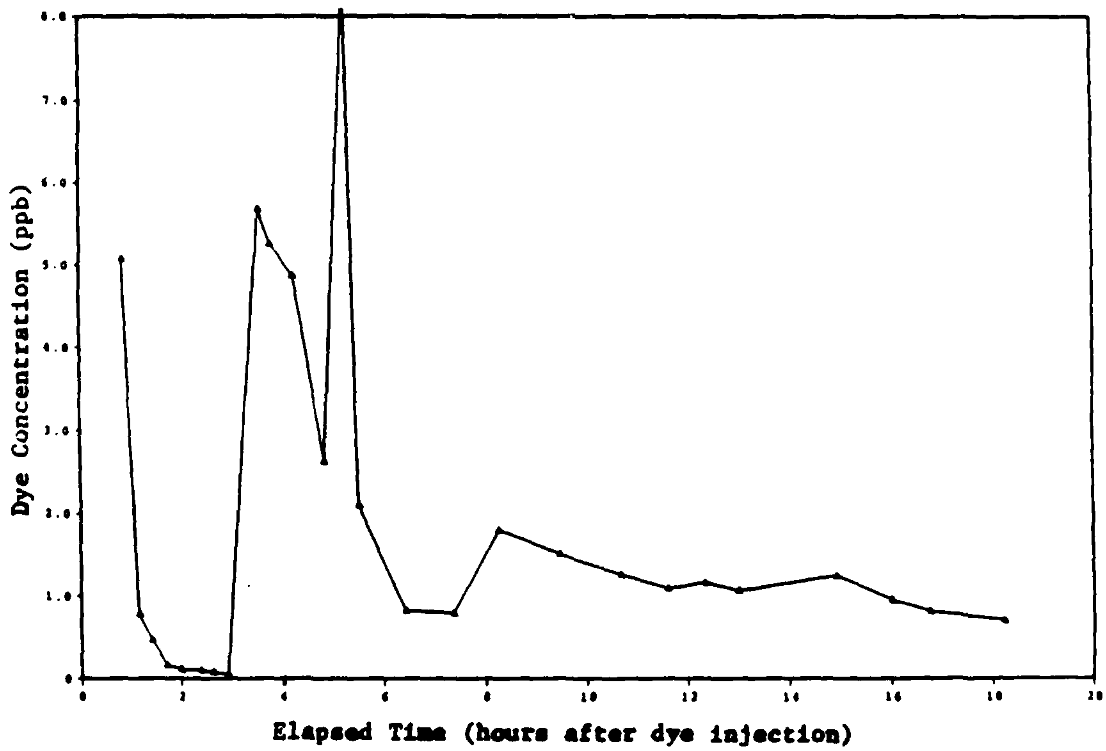


Figure Q4. Huntington Harbour dye study, concentration at Station C (after Tekmarine 1988)

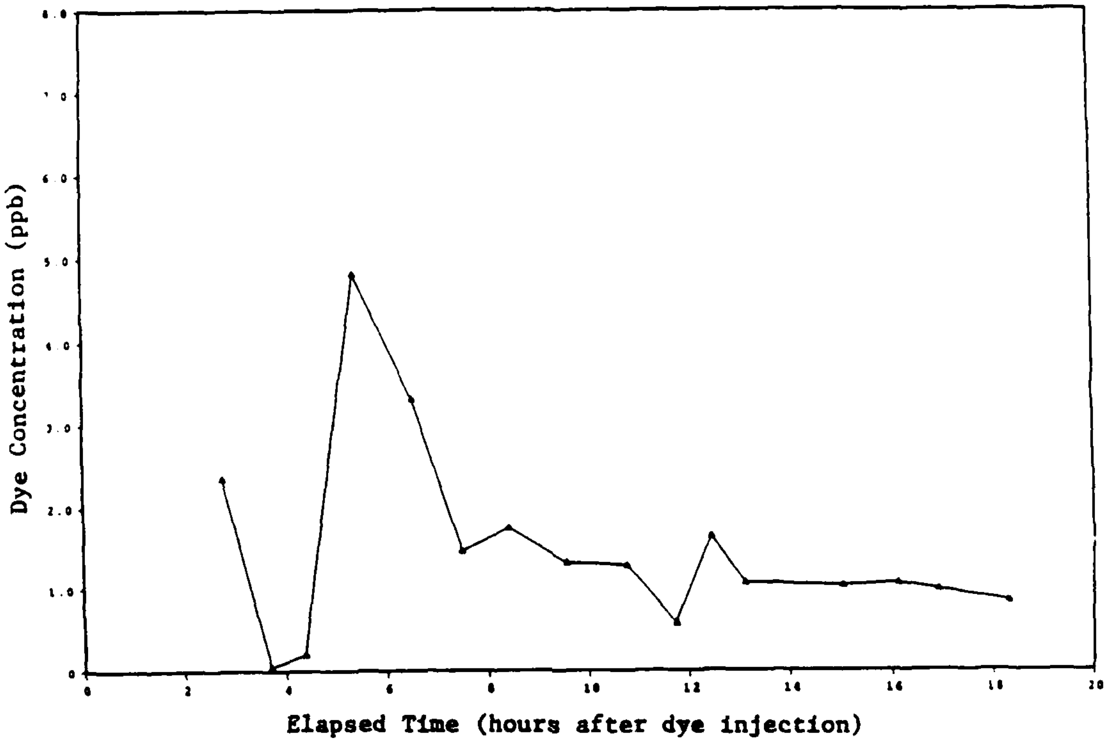


Figure Q5. Huntington Harbour dye study,
concentration at Station D (after Tekmarine 1988)

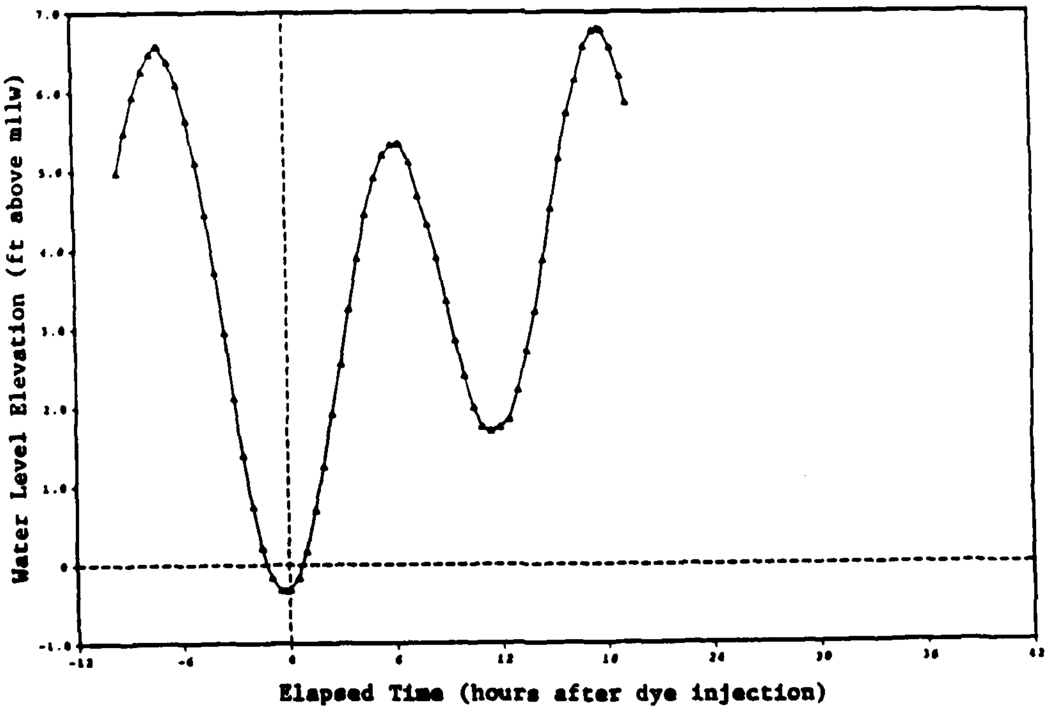


Figure Q6. Huntington Harbour dye study,
tidal record (after Tekmarine 1988)

contaminated while being handled in the field. In any case, it was believed these to be spurious points that should be ignored.

Q10. During the first 4-hr period of sampling at Station A, samples were obtained at mid-depth and at the surface. Generally during this period, the surface concentration was about equal to or lower than that at mid-depth. A notable exception occurred as the initial dye cloud passed Station A at +2.53 hr. The concentration at mid-depth registered 3.25 ppb, while concomitantly, the surface concentration reached 14.20 ppb. It is apparent that the dye had not become well mixed vertically by the time it first reached Station A.

Q11. Contrary to what might be expected, the time-histories of the mid-depth dye concentrations at Stations A and C show an increase as the initial dye cloud passed from A to C (Figures Q2 and Q4). The peak mid-depth concentration rose from 3.25 ppb at Station A to about 5 - 8.5 ppb at Station C. If one considers the poorly-mixed condition that existed at Station A as discussed previously, this mid-depth concentration increase can probably be attributed to an increased degree of vertical mixing as the dye cloud traveled from Station A to Station C. Also, the dual peak concentration measured at Station C indicates that the mixing was not yet complete.

Q12. The weather during the study period consisted of clear, sunny conditions during the daylight hours, and calm during the early morning and evening. The typical southern California sea breeze system produced south-by-southwest winds with maximum speeds of about 10 knots in the early afternoon.

Q13. The tidal cycle measured by the gage installed at the Sunset Aquatic Park coincided closely in time with the occurrence of the high and low water periods predicted by the 1988 NOAA Tide Tables. However, the water level elevations of the highs and lows during the study period were found to be 0.2 to 0.5 ft higher than the predicted values. Since weather conditions were not believed to have been the cause of these differences, possible sources of tide gage datum error were considered. Since the initial survey which transferred the elevation from the benchmark to the tide gage was performed twice with satisfactory agreement, inaccurate leveling procedures were ruled out. To check the accuracy of the reference benchmark, a survey was conducted between this benchmark and a second Orange County Surveyor benchmark (No. HB-239-75) located further inland. No significant

discrepancies were discovered. The Huntington Beach area has been known for having a history of subsidence that has affected local benchmarks; however, a monitoring program conducted by the Orange County Surveyor between 1976-1986 indicates that subsidence along PCH in the vicinity of the tide gage installation was insignificant during this period (total settlement less than about 0.05 ft).

Q14. While it may be possible that the hydraulic characteristics of Huntington Harbour and the entrance through Anaheim Bay serve to modify the tidal regime compared with that predicted for the open water area of San Pedro Bay, it is suggested that a comparison be made between the data recorded for this study and the water level elevations measured by NOAA at the Los Angeles Harbor station (Station 941-0660, L. A. Harbor Berth 60). Such a comparison was not carried out by Tekmarine (1988) since this study was prepared before the NOAA data became available, approximately 6 weeks after the end of September 1988.

Q15. The inconsistencies associated with the Huntington Harbour data set make it difficult to interpret, and impossible to use for comparison to model results. The problems with this data set include incomplete initial mixing, inadequate sampling frequency, and physically unrealistic peak measurements. Immediately following the dye release in Huntington Harbour, the dye concentration varied by over an order of magnitude at the injection site. At the first downstream sampling station, a 4-fold range of dye concentration existed between surface and mid-depth measurements. At Station C, downstream of the injection location from Station A, the mid-depth peak concentration was 2.5 times the peak concentration at Station A. This may have resulted from incomplete mixing or missing the true concentration peak at Station A during sampling. At Stations C and D, concentration peaks were observed at times much earlier than velocity measurements in the system from a previous study would indicate physically possible and, in fact, prior to observation of the first peak at the sampling Station A. Sample contamination or inadvertent early dye release may be responsible for these observations. Samples were not collected frequently enough at stations to observe a clear dye peak. Rising and falling limbs, along with more than one observation near a peak concentration, were not observed in the data.

Bolsa Bay Dye Study

Bolsa Bay field operations

Q16. The dye study in Bolsa Bay was carried out on 8-9 September 1988, and timed to begin after the occurrence of the lower low tide predicted by NOAA at 0254 PDT on the 8th. A total of 6.0 liters of Rhodamine WT (20 per-cent solution) was released in Outer Bolsa Bay at Station F just north of the tide gates separating Outer and Inner Bolsa Bay. Ebbing flow through the tide gates and through Outer Bolsa Bay continues well past the occurrence of slack tide at the ocean entrance to Huntington Harbour. The dye was released at 0320-0330 PDT, approximately in after the predicted low tide, to take advantage of the mixing afforded t e turbulent outflow at the tide gates while limiting its northbound movemer efore it reversed and entered Inner Bolsa Bay with the flood tide. Zero hour for the dye release was specified to be 0325 PDT.

Q17. The sampling operations were conducted at primary Stations F, I, J, and K, and at secondary Stations D, E, G, H. and L. The sampling schedule initially focused on the stations where the early dye cloud would pass. Later, as the peak dye concentrations were expected to have diminished, sampling reverted to a schedule where the four primary stations were sampled every 1 to 2 hr until the end of the study, approximately 36 hr after the release of the dye.

Q18. The sampling procedures used at the various stations depended upon the degree of accessibility to the channel. A small, inflatable boat was used to reach mid-channel/mid-depth at Stations F and G, the footbridge traversing the wetlands permitted access to mid-channel/mid-depth at Station I, and a 15-ft long sampling rod was used from shore at Stations D, E, H, J, K, and L.

Bolsa Bay dye study results

Q19. Figures Q7 through Q10 present time-series of the concentrations measured at the four primary stations. Figure Q11 shows the tidal fluctuations measured by the tide gage installed for the study at the entrance to Huntington Harbour. As shown in Figure Q7, the first few samples taken at the dye release point, beginning only 5 min after completing the injection, are evidence of the rapid northbound transport that prevailed at the time of the injection. To track this movement of the dye cloud, early sampling was

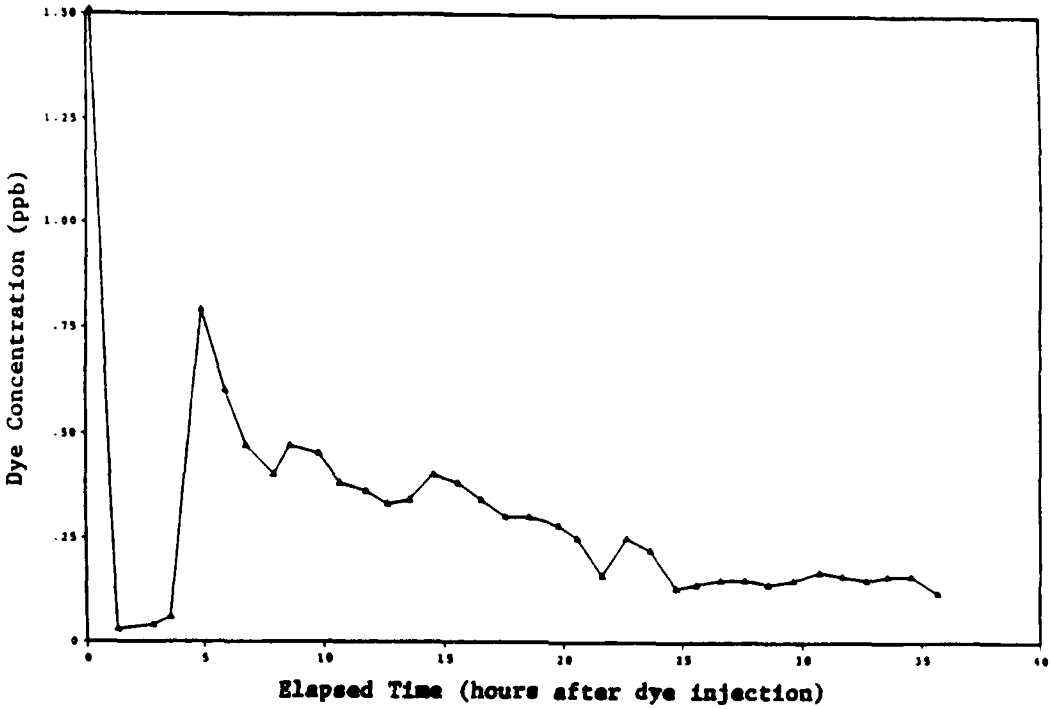


Figure Q7. Bolsa Bay dye study,
concentration at Station F (after Tekmarine 1988)

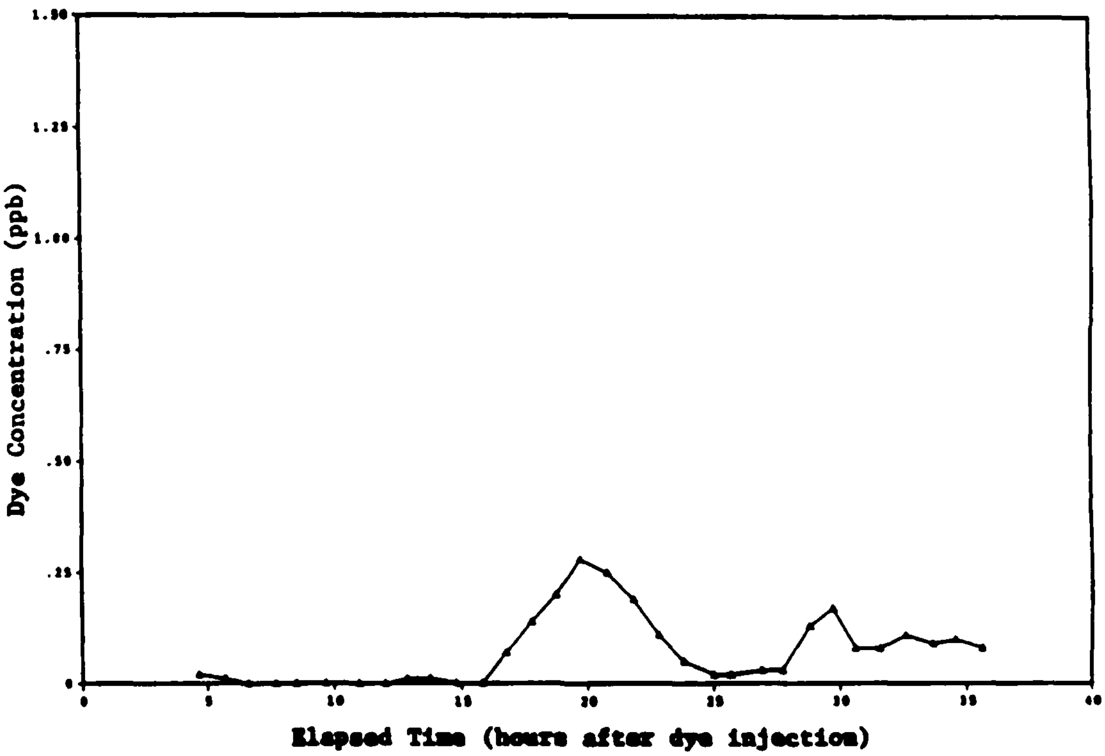


Figure Q8. Bolsa Bay dye study,
concentration at Station I (after Tekmarine 1988)

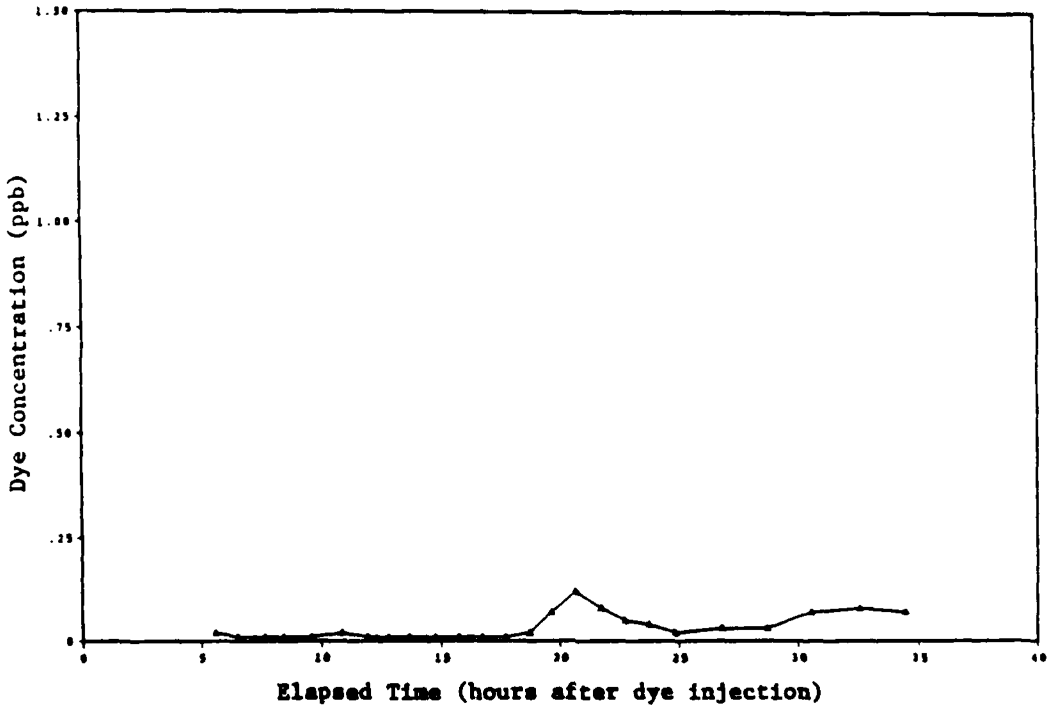


Figure Q9. Bolsa Bay dye study, concentration at Station J (after Tekmarine 1988)

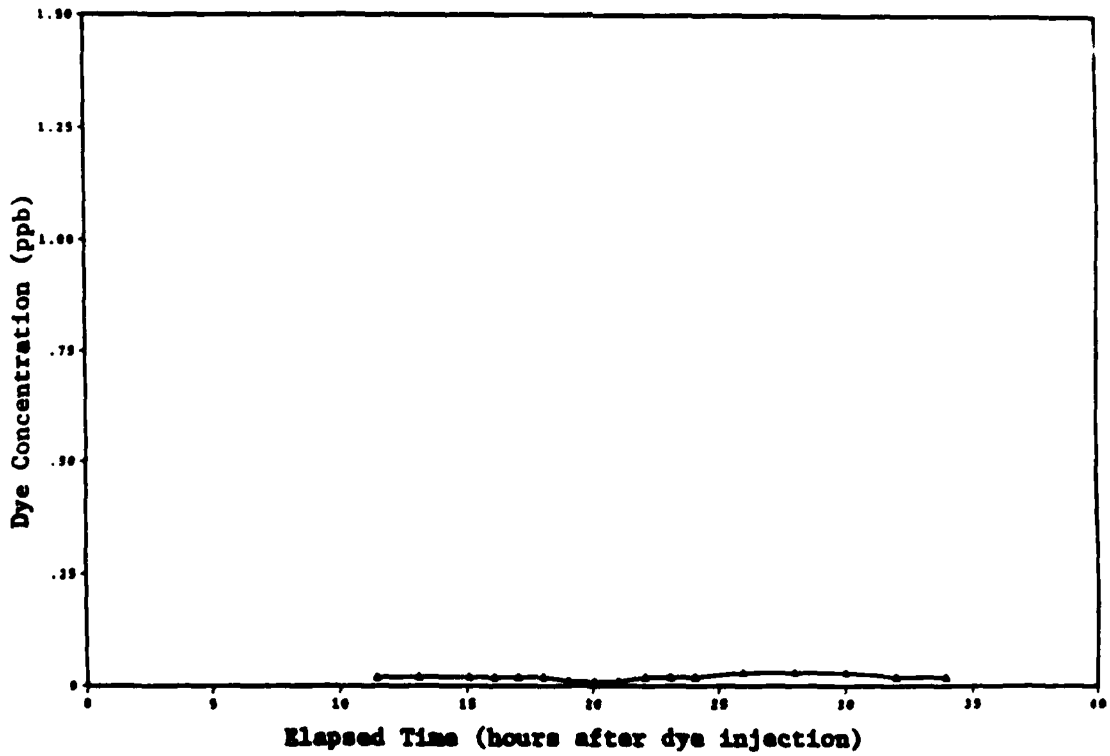


Figure Q10. Bolsa Bay dye study, concentration at Station K (after Tekmarine 1988)

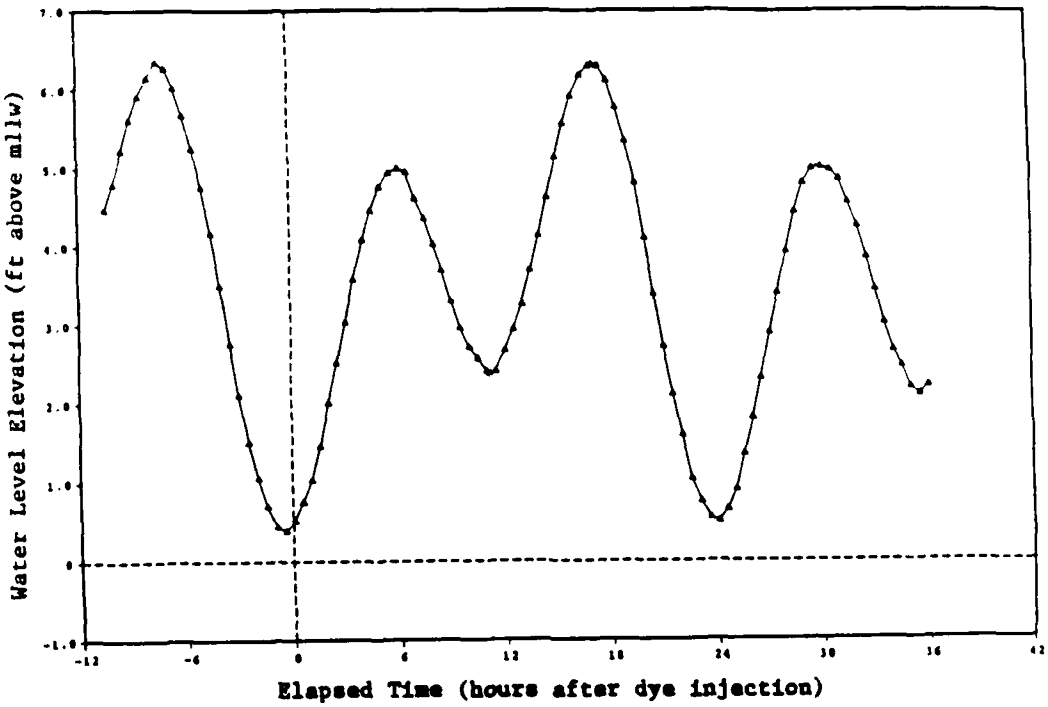


Figure Q11. Bolsa Bay dye study,
tidal record (after Tekmarine 1988)

attempted at Stations E and D. While broad mudflats prevented access to the channel at Station E during low tide, the first sample taken at Station D revealed the highest concentration measured during the entire study, 46.9 ppb.

Q20. As the tidal flows reversed and began to flood the channels, attention was turned to the stations at and south of the tide gates. Comparison of Figures Q7, Q8, and Q9 distinctly shows the lag and peak concentration decrease between stations as the initial dye plume moves into Inner Bolsa Bay. Although the data from Stations G and H show evidence of the initial approach of the dye plume, sampling was stopped in favor of the primary stations, and apparently before the centroid of the plume passed their respective locations.

Q21. Only weak concentrations were measured at Station K, located in the cell most distant from the open ocean. Although no background samples were taken in this portion of the study area, some uncertainty surrounds these measurements as they may reflect the presence of an increased level of background fluorescence rather than the injected dye.

Q22. The weather during the study period consisted of mostly clear, sunny conditions during the daylight hours. During the early morning hours of 8 September, the wind was out of the southeast at roughly 8 to 10 knots. These winds diminished by mid-day. During the evening of the 8th and the morning of the 9th, the winds were calm. The southern California coastal sea breeze system arose on the afternoon of the 9th, producing westerly winds of about 12 to 15 knots.

Q23. The tidal cycle measured by the gage (Figure Q11) showed the same characteristics as the data recorded during the Huntington Harbour study. The chronology of the high and low tides coincided well with the tides predicted by NOAA, but the water level elevations derived from the gage were 0.3 to 0.5 ft higher than the predicted values. Here again, no evidence of error could be detected, and it is recommended that a comparison with the measured NOAA tides be performed when these data become available.